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A Record of NASA Space Missions since 1958

compiled by
Alfred Rosenthal
for the Goddard Space Flight Center

NASA Goddard Space Flight Center
1982

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A Word about NASA's Goddard Space Flight Center

The Goddard Space Flight Center is a partnership of many people – scientists, engineers, project managers, and administrators – whose combined efforts are needed to carry on and bring to fruition scientific and technological expeditions into outer space.

Goddard has been responsible for major advances in communications, weather and climate research, earth resources, space physics, and space astronomy. These accomplishments were achieved concurrent with unprecedented worldwide ground support roles for the Mercury, Gemini, Apollo, and Skylab manned flight missions.

Goddard is also the home of the National Space Science Data Center. This unique facility, housing modern interactive computer facilities, is the nation's central repository for much of the data acquired through space science experimentation. The center has acquired data from over 800 different satellite experiments in all major disciplines from NASA, DOD, NOAA, and foreign government missions.

The Data Center maintains computerized files containing extensive data about 2,738 spacecraft, 3,584 experiments, 3,198 data sets, and 10,398 sounding rocket launches.

Much of the data presented here was collected by the National Space Science Data Center and acquired by the Goddard-managed Space Flight Tracking and Data Network.

The network is a world-wide complex of stations used to provide communications with both manned and unmanned spacecraft. It is operated primarily in direct support of NASA's earth-orbiting scientific and applications satellites and manned spaceflight programs; may also be used in support of other NASA programs such as space probes and sounding rockets. Additionally, the network can support programs of other U.S. agencies, and organizations as well as international space projects.

Since its establishment in 1958 the Goddard team not only opened a new path of exploration but sustained a tradition of scientific and technical curiosity envisioned two generations earlier by a then unknown New England professor – Dr. Robert H. Goddard.

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OF POOR QUALITY

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OF POOR QUALITY

Men love to wonder,

and that is the seed of our science.

Emerson

A Record of NASA Space Missions since 1958

FOREWORD

Dedicated men and women together with a unique team of industries and universities created the U.S. space program. They provided the ideas, developed the hardware, launched the satellites, safely returned our astronauts and successfully retrieved hard-won data from outer space.

In an attempt to document, between two covers, the accomplishments of the 1958-1981 period, this report has been compiled. It is a record of an exciting and often dramatic period in the history of the United States. The National Aeronautics and Space Administration is proud to have been permitted to play such an important role in challenging man's spirit.

James M. Beggs
Administrator

EDITOR'S NOTE

This publication describes major NASA satellite missions during the period of 1958 to 1981. Included are those in support of the U.S. space program, as well as projects conducted in cooperation with private industry and in association with foreign nations.

The data collected in this publication has been gleaned from many sources. Liberal use--including reprints therefrom--has been made of materials published in the Space Log of the TRW Space Systems Group, records compiled by NASA's National Space Science Data Center, and statistics published by the Office of Management Operations, NASA Headquarters. Other sources include the Encyclopedia of Satellites and Sounding Rockets published by the Goddard Space Flight Center, congressional reference documents, and materials from the Library of Congress. Permission to utilize these sources has been gratefully acknowledged.

In the narrative portion of this publication, launch sites, weights, orbital elements, and other statistical data are cited as reported at the time of the event. However, in the interest of uniformity, metric measurements may be found in the listings under "NASA Launch Record."

Where facts and other data appeared in conflict, NASA records are cited. While every effort has been made to assure accuracy of this material, comments, suggestions, and corrections of fact are invited.

Special thanks to Albert B. Matelis for reviewing and proofing this publication in its various states of preparation and production. Also, thanks to Mrs. Ellen Seufert, Ron Craig, and Ms. Susan deSeve for their efforts in locating the photographs which were used to illustrate these pages; to Ms. Darlene Ahalt, Ms. Shirley Deremer, and Ms. Pat Ratkewicz for copy and page production. And to Gene Guerny, Chief, Office of Public Affairs, Goddard Space Flight Center, many thanks for providing access to much of the basic documentation used in this project, together with encouragement and enthusiasm. The cover is the work of artist Maceo Leatherwood. The overall book design was created by Eileen Sapcariu. The graphic layout was designed and executed by Ellen G. Cornett. Without their help it would have been difficult to complete this project.

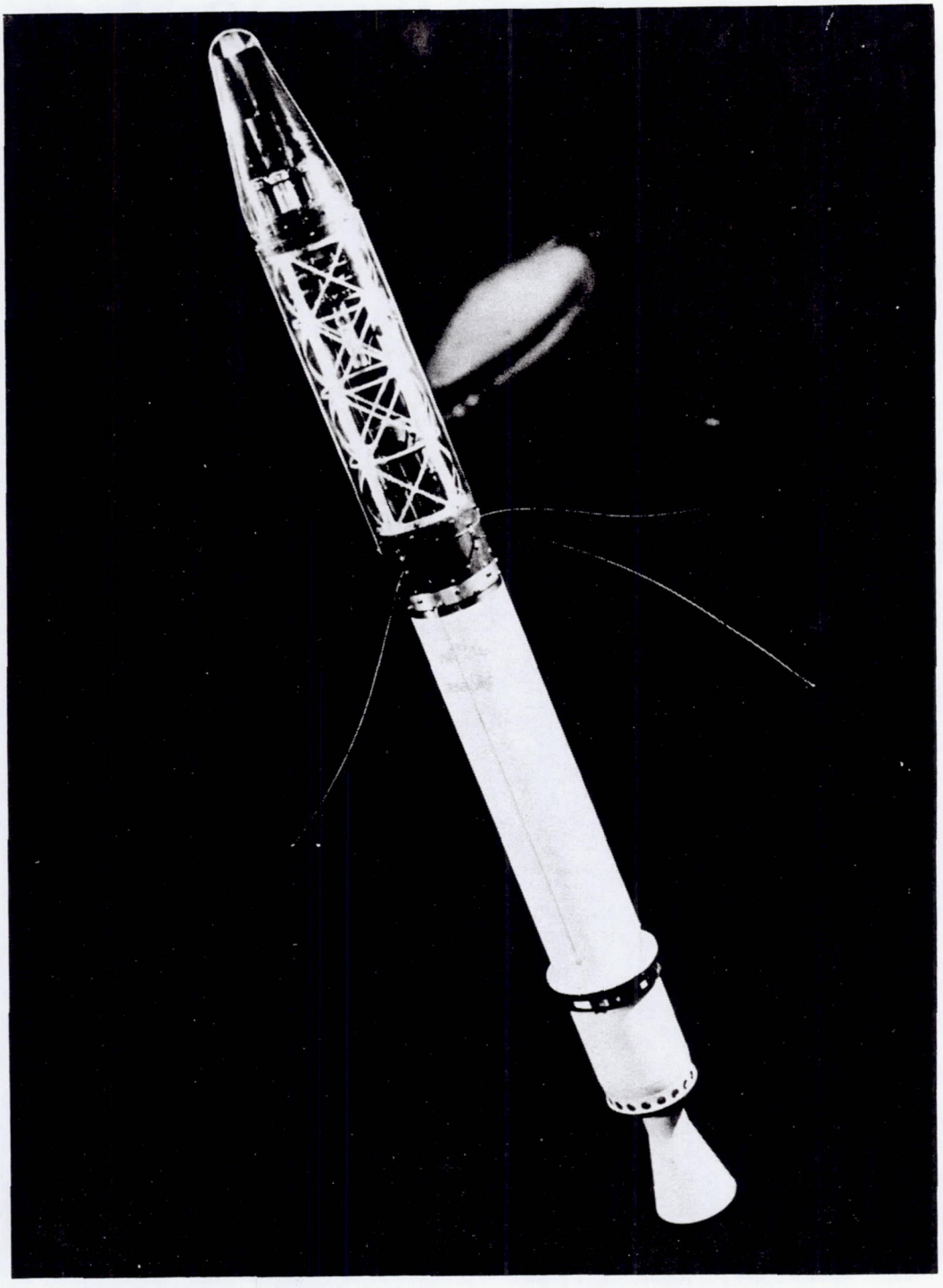
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Major NASA Satellite Missions and Key Participants 1958 - 1981

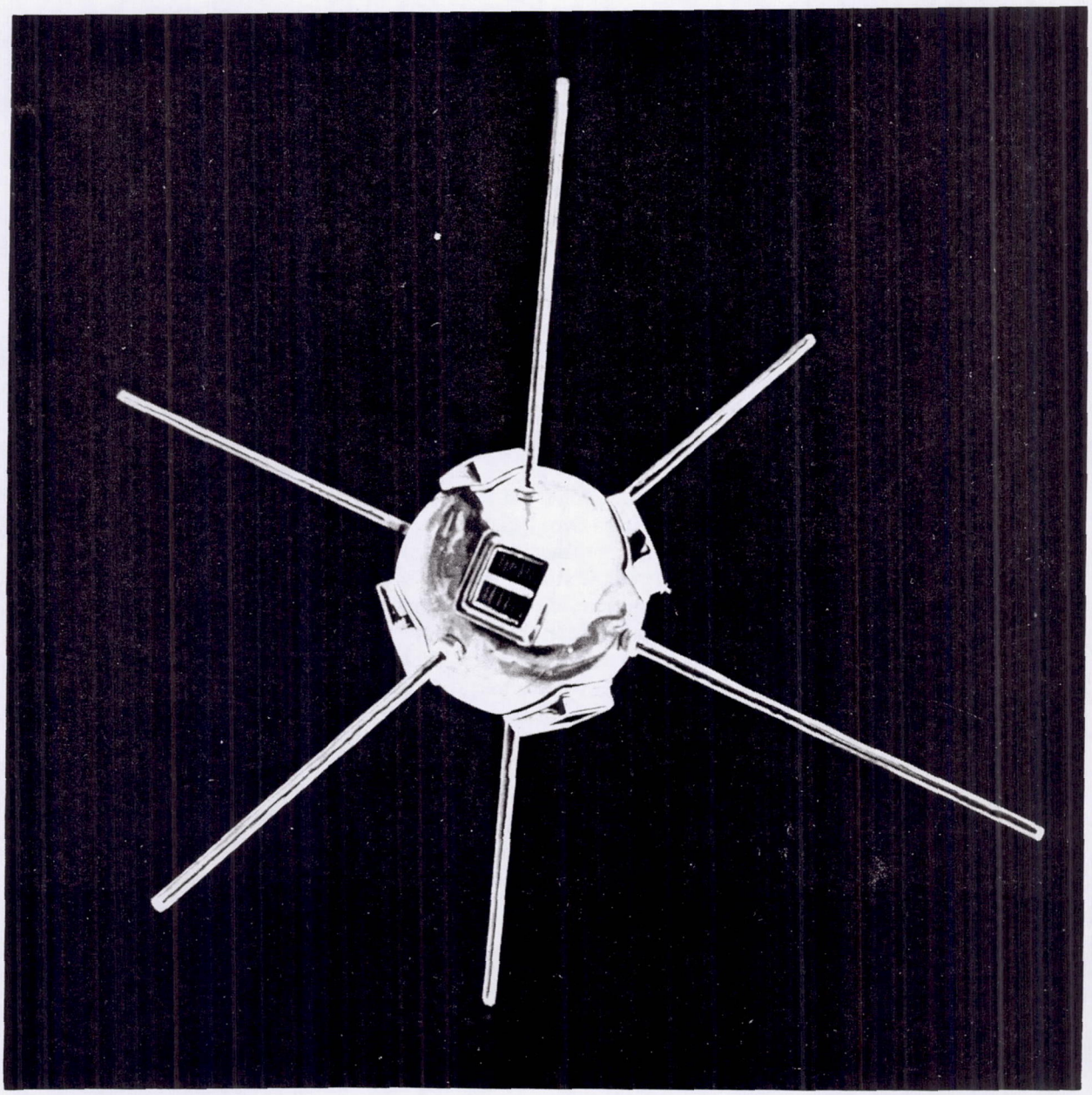
The way it began...



Explorer I, launched on February 1, 1958, was first U.S. satellite placed in orbit. It discovered a radiation belt around the Earth which was identified by Dr. James A. Van Allen, University of Iowa, and was an important discovery of the International Geophysical Year. The satellite stopped transmissions on February 28, 1958.

1958

On March 17, 1958 a Navy team successfully sent Vanguard I, a 6-inch diameter moon, on its orbital mission. Its size was not as great as the 23-inch diameter Sputnik, launched earlier by the USSR, but from Vanguard I, scientists obtained much valuable information about the shape of the Earth and its interior. Tiny but tough, Vanguard I transmitted its signals for nearly 7 years as it circled the globe.



PIONEER I

Launch Vehicle – The three-stage Thor-Able vehicle was comprised of a modified Air Force Thor IRBM (liquid propellant, thrust about 153,000 pounds) as the first stage. A liquid-propellant rocket engine powered the second stage (modified Vanguard second stage, thrust about 7500 pounds). The third stage was a solid-propellant unit based on Vanguard design, rated at 116,500 lb sec total impulse. Gross liftoff weight was more than 105,000 pounds, and total height was 90 feet.

Spacecraft Description – A double toroid; total height of the two cone frustums and a thin cylindrical midsection was 30 inches; midsection diameter was 29 inches. The spacecraft had two additional propulsion assemblies: a ring of eight low-thrust, solid-propellant rockets for postlaunch velocity adjustment and an axially located solid-propellant injection rocket. The velocity-adjustment rocket assembly was jettisoned after use; the injection-rocket case was the main structural member of the spacecraft. Spacecraft total weight after vernier separation, 75.3 pounds; spacecraft total weight after firing injection rocket, 51.1 pounds; instrument package weight, 39.6 pounds. Shell composition: laminated plastic.

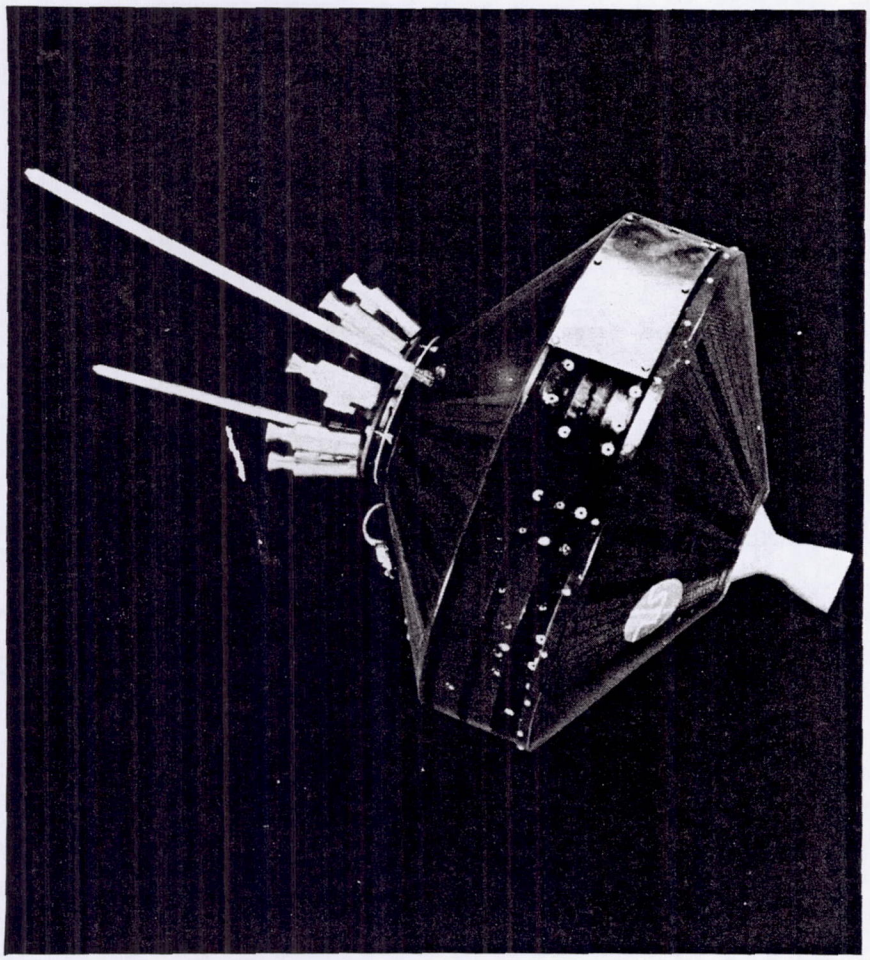
Spacecraft Payload – Instrumentation: measurement of radiation in space (up to 1000 roentgens per hour, plus) with ionization chamber determination of density of micrometeorite matter with a diaphragm/microphone assembly; measurement of magnetic fields around earth or moon (down to minimum of 5 microgauss) with a spin-coil magnetometer; study of moon's surface (to resolution of 1 milliradian) with an image-scanning infrared television system; recording of internal conditions with temperature-variable resistors. Antennas: a magnetic dipole for television system; an electric dipole for telemetry transmitter and for receiving ground commands at 115 megacycles. Transmitters: a) television system operated on 108.09 megacycles at peak power of 50 watts; b) telemetry transmitter on 108.06 megacycles at 300 milliwatts. Power Supply: nickel-cadmium batteries for ignition circuits of vernier and injection rockets, silver-cell batteries for television system, and mercury batteries for remaining circuits. Transmission Duration: stopped at re-entry.

Test Results – Pioneer I reached a peak altitude of 70,700 miles after launching from Cape Canaveral on October 11, 1958. Because of a slight error in burnout velocity and angle, this spacecraft did not reach the moon. It re-entered the atmosphere over the South Pacific on October 12, 1958. Important results were: a) determination of radial extent of radiation band, and first observation that radiation is a band; b) mapping of total ionizing flux; c) first observations of hydromagnetic oscillations of magnetic field from theoretical prediction; e) first determination of density of micrometeors in interplanetary space; f) first measurements of interplanetary magnetic field.

Participants – Air Force Ballistic Missile Division, National Aeronautics and Space Administration, Space Technology Laboratories, Inc., Douglas Aircraft Company, Aerojet-General Corporation, Rocketdyne, Allegany Ballistics Laboratory, Thiokol Chemical Corp., Naval Ordnance Test Station.

Key Spacecraft Personnel		Affiliation
PM	C.F. Hall	NASA-ARC

Experiment	Experiment Personnel		Affiliation
Ionization Chamber	PI	C.P. Sonett	University of Arizona
	OI	P.J. Coleman, Jr.	University of California
	OI	A. Rosen	TRW Systems Group
Search Coil Magnetometer	PI	C.P. Sonett	University of Arizona
Micrometeorite Measurements	PI	M. Dubin	NASA-GSFC
Lunar TV Scanner	PI	Unknown	Unknown



Pioneer I was launched on October 11, 1958 by a Thor-Able booster. While it failed to reach the Moon, it did return 43 hours of data. (Photo of model)

BEACON I

Launch Vehicle – The four-stage Jupiter C, first used for re-entry experiments, was adapted to this task and renamed Juno I. The first stage was a Redstone missile (liquid propellant, uprated to 83,000 pounds of thrust) with a long interstage structure replacing the warhead. The upper three stages, called the high-speed stages, were made up of 15 scaled-down Sergeant rockets (solid propellant) in the following arrangement: the second stage was assembled as a "tub" of 11 Sergeant units; the third stage was assembled as three Sergeant units nested in the center of the "tub"; and a single modified Sergeant comprising the fourth stage was mounted on top of the third stage. The three upper stages were rotated as a unit by electric motors before and during launch for attitude stabilization. Total height was 68.6 feet.

Spacecraft Description – The final object was a thin plastic sphere (after inflation) weighing 9.26 pounds and measuring 12 feet in diameter. Shell composition: Mylar polyester film coated with microthin aluminum foil. The Beacon final stage differed from the Explorer configurations in several respects: The Beacon stage had a total length of 50 inches and a diameter of 7 inches, and was made up of two sections held together by a clamp ring. The solid-propellant rocket unit weighed 11.27 pounds, and the payload case weighed 18.3 pounds. The payload section contained the folded sphere, a radio beacon, a solid-propellant kick motor (to accelerate the payload section by the kick-in-the-apogee method), a pressure bottle, and a sphere ejection system.

Program Objectives – Experiments: ejection of sphere from payload package; sphere itself to be used to study atmosphere density at various levels during estimated lifetime of about two weeks.

Spacecraft Payload – Transmitters: none in sphere; radio beacon in payload case.

Test Results – Launch was made from Cape Canaveral on October 23, 1958. Part of the high-speed stages, including payload, separated from the Redstone first stage prior to first-stage burnout. Flight time of payload, 424 seconds; flight time of first stage, 526 seconds.

Participants – National Aeronautics and Space Administration, Jet Propulsion Laboratory, Army Ballistic Missile Agency, Chrysler Corporation, Sperry Rand Corporation.

PIONEER II

Launch Vehicle – Same as Pioneer I.

Spacecraft Description – Same as Pioneer I, except that total weight of payload after vernier-rocket separation was 86.3 pounds.

Spacecraft Payload – Same as Pioneer I, except: 1) STL image-scanning television system replaced that of Pioneer I; 2) a proportional counter (for radiation measurements) was added; and 3) the magnetic dipole was adapted to a 108.09-megacycle telemetry transmitter.

Test Results – Pioneer II was launched on November 8, 1958, from Cape Canaveral. Third-stage rocket failed to ignite. Re-entered atmosphere at 28.7°N and 1.9°E after reaching peak altitude of 963 miles. Highlights of flight were: 1) evidence that equatorial region about earth has higher flux and higher energy radiation than previously considered, and 2) suggestion that micrometeoric density is higher around earth than in space.

Participants – Same as Pioneer I.

Key Spacecraft Personnel		Affiliation
PM	C.F. Hall	NASA-ARC

Experiment	Experiment Personnel		Affiliation
Ionization Chamber	PI	C.P. Sonett	University of Arizona
	OI	P.J. Coleman, Jr.	University of California
	OI	A. Rosen	TRW Systems Group
Search Coil Magnetometer	PI	C.P. Sonett	University of Arizona
Micrometeorite Measurements	PI	M. Dubin	NASA-GSFC
Lunar TV Scanner	PI	Unknown	Unknown

PIONEER III

Launch Vehicle – The four-stage Juno II launching vehicle was made up of existing missile stages. The first stage was a modified Jupiter IRBM (liquid propellant), topped by an interstage structure replacing the nose-cone assembly. The high-speed stages were made up of 15 scaled-down Sergeant rockets (solid propellant) in the following arrangement: the second stage was assembled as a "tub" of 11 Sergeant units; the third stage was assembled as a cluster of three Sergeants nested in the center of the "tub", and the fourth stage was a single Sergeant, mounted on top of the third stage. The high-speed stages were rotated as a unit by two integral electric motors before and during launch to achieve attitude stabilization. Total height, including conical nose fairing, 76.7 feet; gross liftoff weight, 121,000 pounds.

Spacecraft Description – Cone; 12.95 pounds; 23 inches high and 10 inches in diameter. Shell composition: gold-washed fiberglass painted with white stripes to control internal temperature.

Spacecraft Payload – Instrumentation: two Geiger-Mueller counters for measurements of radiation in space; photoelectric sensing "trigger" for a scanning device intended for later probe. Antenna: tip probe and cone itself served as antenna; gold film was conductor. Transmitter: 960.05 megacycles at 180 milliwatts. Power Supply: mercury batteries. Transmission Duration: stopped at re-entry.

Test Results — Pioneer III reached a peak altitude of 63,580 miles after launching from Cape Canaveral on December 6, 1958. Because of a slight error in burnout velocity and angle, Pioneer III did not reach the moon. The 10.25-pound fourth-stage casing also was injected into a departure orbit. Second radiation belt around earth was discovered, however, during flight. Re-entered atmosphere over French Equatorial Africa (estimated at 16.4°N and 18.6°E) on December 7, 1958.

Participants – National Aeronautics and Space Administration, Jet Propulsion Laboratory, Army Ballistic Missile Agency, Chrysler Corporation, Sperry Rand Corporation, Rocketdyne.

Key Spacecraft Personnel	Affiliation
PM Jack E. Froelich	JPL
PS None	
MG Edgar M. Cortright	

Experiment	Experiment Personnel	Affiliation
Geiger Counters	PI J.A. Van Allen	University of Iowa

VANGUARD TEST VEHICLE 3

Launch Vehicle – The first stage of the three-stage Vanguard Test Vehicle was propelled by a liquid-propellant, 27,000-pound-thrust rocket engine. The second stage utilized a liquid-propellant, 7500-pound-thrust rocket engine; this stage contained the complete guidance and control system. A solid-propellant rocket with 2350 pounds of thrust (for 30 seconds burning time) was developed to satisfy third-stage requirements. The total height of the vehicle was about 72 feet; finless; base diameter, 45 inches; gross lift-off weight, 22,600 pounds.

Spacecraft Description – Sphere; 3.25 pounds; 6 inches in diameter. Shell composition: aluminum.

Program Objectives – To conduct micrometeor impact and geodetic measurements.

Spacecraft Payload – Antennas: one turnstile antenna; one dipole antenna with a total of six 12-inch rod elements. Transmitters: a) 108.00 megacycles at 10 milliwatts; b) 108.03 megacycles at 5 milliwatts. Power Supply: a) mercury batteries; b) six groups of solar cells.

Test Results – Vehicle lost thrust after two seconds of attempt to launch from Cape Canaveral, on December 6, 1957, and was consumed in flames. Cause was attributed to a malfunction in the first-stage power plant.

Participants – Naval Research Laboratory, The Martin Company, General Electric Company, Aerojet-General Corporation, Grand Central Rocket Company.

VANGUARD TEST VEHICLE 3 BACKUP

Launch Vehicle – Same as Vanguard Test Vehicle 3.

Spacecraft Description – Same as Vanguard Test Vehicle 3.

Spacecraft Payload – Same as Vanguard Test Vehicle 3.

Test Results – After a successful liftoff from Cape Canaveral and 57 seconds of flight, a connection between units of first-stage control system failed to function. At an altitude of 20,000 feet, the rocket veered off course with such force that it snapped apart and fell. Date, February 5, 1958.

Participants – Same as Vanguard Test Vehicle 3.

Note: Some of these activities predate the establishment of the National Aeronautics and Space Administration. They have been included because of their historical significance representing the early and trying efforts of the U.S. space program, intended to launch at least one satellite during the International Geophysical Year.

Vanguard Test Vehicles had the potentiality of launching satellites in late 1957 and early 1958, although their main purpose was system testing. Unfortunately, the failures were widely publicized as satellite-launch failures, rather than tests.

VANGUARD TEST VEHICLE 4

Launch Vehicle – Same as Vanguard Test Vehicle 3.

Spacecraft Description – Sphere; 3.25 pounds; 6.4 inches in diameter. Shell composition: aluminum, coated with thin film of silicon monoxide.

Program Objectives – To develop capability to launch satellites into accurate earth orbits; to test and confirm feasibility of the Vanguard concept; to conduct geodetic and temperature measurements.

Spacecraft Payload – Instrumentation: crystal of one radio was placed in thermal contact with internal structure, and the other crystal was placed in thermal contact with outer shell. Absolute temperatures of the two structures could be determined from change in signal frequency of each radio, while transmitting. Antennas: one turnstile antenna; one dipole antenna with a total of six 12-inch rod elements. Transmitters: a) 108.00 megacycles at 10 milliwatts; b) 108.03 megacycles at 5 milliwatts. Power Supply: transmitter a) used mercury batteries, and b) energized by six groups of solar cells. Transmission Duration: transmitter a) ceased operating on April 5, 1958; b) was expected to transmit for the lifetime of the satellite.

Test Results – Vanguard I was successfully launched on March 17, 1958, from Cape Canaveral. Expended cylindrical case, 20 inches in diameter, 4 feet in length, and weighing 50 pounds, went into orbit along with spacecraft. The Army Map Service had been making electronic observations of the satellite from Pacific Islands to pinpoint its location more exactly. The satellite was also being used for more exact determination of earth's geodesy (shape, etc.) by use of Minitrack and Microlock installations.

Participants – Same as Vanguard Test Vehicle 3.

VANGUARD TEST VEHICLE 5

Experiment	Experiment Personnel	Affiliation
Geiger Counter	Unknown	Unknown
Micrometeoroid Gauge	Unknown	Unknown
Proton-Precession Magnetometer	J.P. Heppner	NRL

Launch Vehicle – Same as Vanguard Test Vehicle 3.

Spacecraft Description – Sphere; 21.5 pounds; 20 inches in diameter. Shell composition: magnesium, coated with highly polished silicon monoxide.

Program Objectives – To conduct measurements of X-radiation from the sun and environmental measurements.

Spacecraft Payload – Antennas: four metal rods. Transmitter: 108.00 megacycles at 80 milliwatts (tracking and telemetry). Power Supply: mercury batteries.

Test Results – Vanguard Test Vehicle 5 was launched from Cape Canaveral on April 28, 1958. Two minor components (electric relays) malfunctioned and failed to transmit the signal for the third stage to fire. Second and third stages impacted 1500 miles from the launch site; this completed the test vehicle series.

Participants – Same as Vanguard Test Vehicle 3.

VANGUARD SATELLITE LAUNCHING VEHICLE 1

Launch Vehicle – Same as Vanguard Test Vehicle 3.

Spacecraft Description – Sphere; 21.5 pounds; 20 inches in diameter. Shell composition: magnesium, coated with highly polished silicon monoxide.

Program Objectives – To develop capability to launch satellites into accurate earth orbits; to confirm the feasibility of the Vanguard concept; to study solar Lyman-alpha radiation and space environment.

Spacecraft Payload – Antennas: four metal rods. Transmitters: 108.00 megacycles at 80 milliwatts. Power Supply: mercury batteries. Transmission Duration: same as flight time, i.e., 20 minutes.

Test Results – Vanguard Satellite Launching Vehicle 1 was launched on May 27, 1958, from Cape Canaveral. Second-stage rocket engine did not cut off properly because of instability resulting from depletion of oxidizer. This caused the vehicle to fly in nose-upward attitude rather than parallel to earth. This in turn caused third stage to fly in high arc-like trajectory. Third stage of vehicle reached peak altitude of 2200 miles and traveled 7500 miles downrange from Cape Canaveral, landing near east coast of Union of South Africa.

Participants – Same as Vanguard Test Vehicle 3.

VANGUARD SATELLITE LAUNCHING VEHICLE 2

Launch Vehicle – Same as Vanguard Test Vehicle 3.

Spacecraft Description – Same as Satellite Launching Vehicle 1. Shell composition: magnesium, coated with highly polished silicon monoxide.

Program Objectives – To measure X-radiation from sun and environment in space.

Spacecraft Payload – Antennas: four metal rods. Transmitter: 108.00 megacycles at 80 milliwatts for tracking and telemetry. Power Supply: mercury batteries.

Test Results – An attempt to place the payload of Satellite Launching Vehicle 2 into orbit was made on June 26, 1958, from Cape Canaveral. Low chamber pressure caused premature cutoff of second-stage rocket engine and termination of flight.

Participants – Same as Vanguard Test Vehicle 3.

VANGUARD SATELLITE LAUNCHING VEHICLE 3

Launch Vehicle – Same as Vanguard Test Vehicle 3.

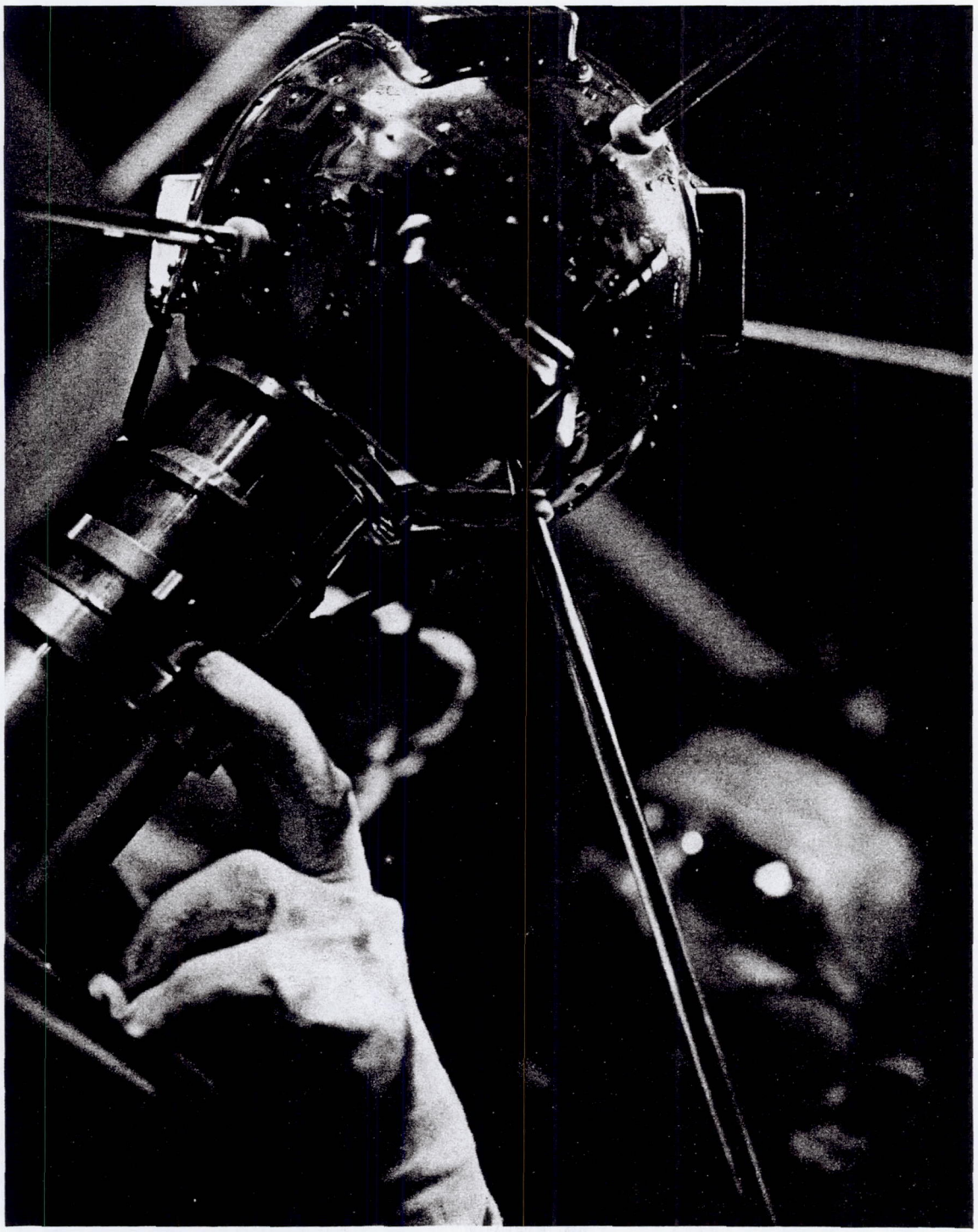
Spacecraft Description – Same as Vanguard Satellite Launching Vehicle 1, Shell composition: magnesium.

Spacecraft Payload – Instrumentation: scan cloud cover of earth with two infrared-sensitive photocells. Antennas: one turnstile antenna with four 30-inch, spring-loaded rod elements. Transmitters: a) 108.00 megacycles at 10 milliwatts; b) 108.03 megacycles at 1 watt. Power Supply: mercury batteries.

Test Results – On September 26, 1958, Vanguard Satellite Launching Vehicle 3 was launched from Cape Canaveral. Second stage failed to achieve minimal performance, causing vehicle to re-enter the atmosphere and burn up. The spacecraft was believed to have made one complete orbit of earth before destruction over Central Africa.

Participants – National Aeronautics and Space Administration, Naval Research Laboratory, General Electric Company, Aerojet-General Corporation, Grand Central Rocket Company.

1959



Last Vanguard Satellite being prepared for launch. The Vanguard program was completed on September 18, 1959 with the successful launch of Vanguard III.

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VANGUARD II SATELLITE LAUNCHING VEHICLE 4

Launch Vehicle – Same as Vanguard Test Vehicle 3.

Spacecraft Description – Sphere; 20.7 pounds; 20 inches in diameter. Shell composition: magnesium, coated with highly polished silicon monoxide.

Program Objectives – To measure sunlight reflected from the cloud cover and from earth's surface.

Spacecraft Payload – Instrumentation: sphere contained two photocell units, recorder (50-minute capacity), radio transmitter and receiver, and Minitrack beacon transmitter. Antennas: four metal rods. Transmitters: a) 108.00 megacycles at 10 milliwatts; b) 108.03 megacycles at 80 milliwatts, triggered by ground station. Power Supply: mercury batteries. Transmission Duration: a) 23 days; b) 27 days.

Test Results – Vanguard II was successfully launched from Cape Canaveral at an inclination of 32.88 degrees to the equator. When it was injected into orbit on February 17, 1959, it became the first cloud-cover satellite. In general, the satellite and its instrumentation functioned as planned. However, interpretation of data has been difficult because satellite developed a precessing (wobbling) motion. Third-stage case went into orbit with spacecraft.

Participants – National Aeronautics and Space Administration, Army Signal Corps, The Martin Company, General Electric Company, Aerojet-General Corporation, Grand Central Rocket Company.

By the time Vanguard II was launched, the National Aeronautics and Space Administration had been created and the program was transferred out of the Naval Research Laboratories.

PIONEER IV

Launch Vehicle – Same as Pioneer III.

Spacecraft Description – Cone; 13.4 pounds; 20 inches high and 9 inches in diameter at base.

Spacecraft Payload – Same as Pioneer III.

Test Results – Pioneer IV was successfully launched on March 3, 1959. After rising from Cape Canaveral, this probe achieved its primary mission (an earth-moon trajectory), yielded excellent radiation data, and provided a valuable tracking exercise. It is now orbiting the sun, the first American solar satellite to be established. Although the probe reached the vicinity of the moon, it did not come close enough (20,000 miles) to trigger the photoelectric sensor or to sample the moon's radiation. The probe passed within 37,300 miles of the moon at 5:25 p.m. on March 4, 1959; it passed 7.2°E and 5.7°S of the moon at 4490 mph. Probe reached perihelion at 9 p.m. on March 17, 1959; injection velocity of 24,790 mph was 188 mph below planned velocity. Pioneer IV was tracked for 82 hours to a distance of 407,000 miles (a record at that time). Fourth-stage cylindrical case, 68 inches long, 6 inches in diameter, and weighing 10.25 pounds, went into orbit with spacecraft.

Participants – Same as Pioneer III.

Key Spacecraft Personnel		Affiliation
PM	Unknown	Unknown
PS	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
Geiger-Mueller Detectors	PI	J.A. Van Allen	University of Iowa
	OI	L.A. Frank	University of Iowa

VANGUARD SATELLITE LAUNCHING VEHICLE 5

Launch Vehicle – Same as Vanguard Test Vehicle 3.

Spacecraft Description – Payload consisted of two independent spheres: Vanguard 3A, a 13-inch sphere with a 2½-inch-diameter cylinder, 17½ inches long, extending from it; Vanguard 3B, a 30-inch inflatable sphere, containing no instrumentation, for optical tracking. Total weight of payload, 23.3 pounds. Shell composition: 3A, fiberglass and phenolic resins; 3B, laminated aluminum foil on plastic sheet.

Spacecraft Payload – Instrumentation: Vanguard 3A contained a precise magnetometer to be used to map earth's magnetic field. Vanguard 3B was to be accurately tracked by earth-based optical instruments to measure drag in space. Antennas: four spring-lock rods. Transmitters: 3A, 108.00 megacycles at 10 milliwatts (tracking) and 108.03 megacycles at 80 milliwatts (telemetry, on ground command). Power Supply: silver-zinc batteries.

Test Results – Second stage failed to operate properly because of damage to the thrust chamber at stage separation, and a tumbling motion resulted. Payload and third stage fell into Atlantic Ocean several hundred miles off Cape Canaveral. Total flight time, about 500 seconds. Launch site, Cape Canaveral; date, April 13, 1959.

Participants – National Aeronautics and Space Administration, The Martin Company, General Electric Company, Aerojet-General Corporation, Grand Central Rocket Company.

VANGUARD SATELLITE LAUNCHING VEHICLE 6

Launch Vehicle – Same as Vanguard Test Vehicle 3.

Spacecraft Description – Sphere; 21.5 pounds; 20 inches in diameter. Shell composition: magnesium alloy.

Program Objectives – To measure solar-earth heating process which generates weather.

Spacecraft Payload – Antennas: four metal rods. Transmitters: a) 108.00 megacycles at 10 milliwatts, b) 108.03 megacycles at 100 milliwatts. Power Supply: mercury batteries.

Test Results – On June 22, 1959, Vanguard Satellite Launching Vehicle 6 rose from its launching pad at Cape Canaveral. Faulty second-stage pressure valve caused the flight to fail. Regulator designed to control helium flow, which forces second-stage propellant into engine, did not respond to command. Pressure built up within helium reservoir, which ruptured about 40 seconds after second-stage engine operated roughly. Helium tank burst when vehicle was at an altitude of 40 to 50 miles. Rocket rolled over in a ballistic trajectory at an altitude of about 90 miles. Third stage ignited before plunging into Atlantic Ocean some 300 miles northeast of Cape Canaveral.

Participants – Same as Vanguard Satellite Launching Vehicle 5.

VANGUARD III

Launch Vehicle – Same as Vanguard Test Vehicle 3.

Spacecraft Description – A solar-powered magnesium sphere with magnetometer boom. The satellite was orbited with the final stage of the launch vehicle, accounting for the high in-orbit mass.

Program Objectives – To measure the Earth's magnetic field, X-ray radiation from the Sun, and several aspects of the space environment through which the satellite travels.

Spacecraft Payload – Proton-precession magnetometer; micrometeoroid detectors; two solar X-ray ionization chambers.

Test Results – Vanguard III was successfully launched from Cape Canaveral on September 18, 1959. Its orbital elements were 319 miles perigee, 2,329 miles apogee. This satellite provided a comprehensive survey of the Earth's magnetic field over the area covered; surveyed location of lower edge of Van Allen radiation belts, accurate count of micro-meteorite impacts.

Participants – Same as Vanguard Satellite Launching Vehicle 5.

Key Spacecraft Personnel		Affiliation
PM	Unknown	US Naval Research Laboratory
PS	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
Proton Precession Magnetometer	PI	J.P. Heppner	NASA-GSFC
X-Ray, Ionization Chambers	PI	H.D. Friedman	US Naval Research Laboratory
Micrometeorite Detector	PI	H.E. Lagow	NASA-GSFC
Atmospheric Drag Density	PI	L.G. Jacchia	SAO
	OI	J.R. Slowey	SAO

EXPLORER (S-1)

Launch Vehicle – Juno II

Spacecraft Description – Two truncated cones joined at bases; 91.5-pound total weight; 28 inches high and 30 inches in diameter.

Program Objectives – To measure earth's radiation balance; Lyman-alpha X-rays; heavy primary cosmic rays; micrometeorites; cosmic rays; and satellite temperatures. Erosion study on an exposed solar (silicon) cell on satellite surface.

Spacecraft Payload – Transmitters: a) 20 megacycles at 650 milliwatts; b) 108 megacycles at 15 milliwatts. Power Supply: chemical batteries continuously charged by solar cells.

Test Results – The launching vehicle had to be destroyed by range safety officer 5½ seconds after liftoff from Cape Canaveral, when it tilted sharply as a result of failure of power supply to guidance system. Date, July 16, 1959.

Participants – National Aeronautics and Space Administration, Jet Propulsion Laboratory, Army Ballistic Missile Agency, Chrysler Corporation, Rand Corporation.

Note: The United States' first satellite exploration program, Explorer, was begun by The Advanced Research Projects Agency (ARPA) and subsequently came under NASA cognizance. The first Explorer launch in January 1958 provided both the first U.S. satellite in orbit and the discovery of the Van Allen radiation belt.

EXPLORER VI

Launch Vehicle – The three-stage Thor Able vehicle was made up of a modified Air Force Thor IRBM (liquid propellant, thrust about 153,000 pounds) as the first stage. A liquid-propellant rocket engine powered the second stage (modified Vanguard second stage, thrust about 7500 pounds). The third stage was the Altair solid-propellant unit (based on Vanguard design) rated at 116,500 lb sec total impulse. Gross liftoff weight was more than 105,000 pounds, and total height was 90 feet.

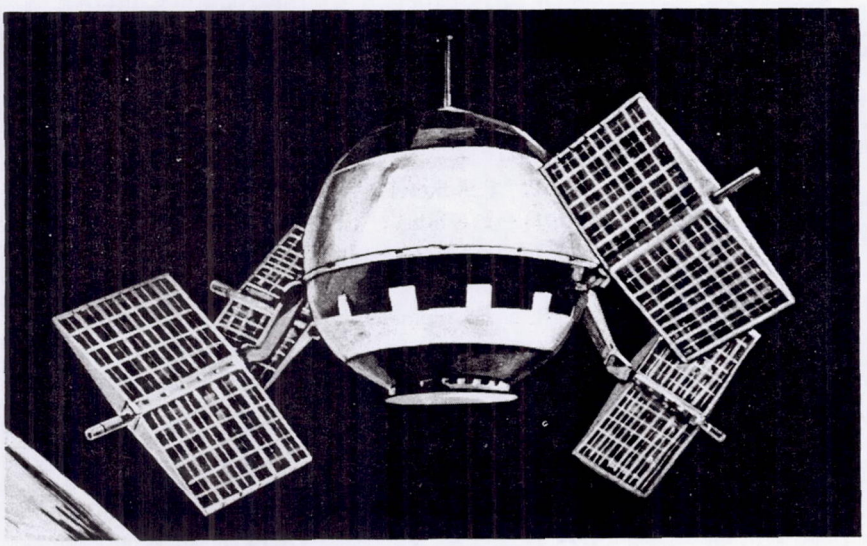
Spacecraft Description – An irregular spheroid with a slightly flattened bottom, and with four solar-cell paddles extended on arms from waist of spacecraft. Total weight, 142 pounds; spheroid diameter, 26 inches; envelope diameter, 86 inches (paddles extended); height, 29 inches (including interstage attachment at bottom). Solar paddles, 20 by 22 inches on surface. Backbone of body is a 5-pound-thrust Atlantic Research 1KS 420 solid-propellant orbit-adjustment rocket (to raise apogee or perigee, if needed). Shell composition: aluminum alloy.

Spacecraft Payload – Instrumentation: 1) measurement of three specific radiation levels of earth's radiation belt by means of a Geiger-Mueller counter and ionizing-chamber combination, a scintillation counter, and a proportional counter telescope; 2) relay of cloud-cover pictures by means of an image-scanning television system (essentially same as Pioneer II design); 3) analysis of both total influx and energy level of micrometeorites encountered by a diaphragm/microphone combination that permits a two-level discrimination of impact energy (essentially the Pioneer I design, where exterior diaphragm equals a predetermined fraction of total surface area of spacecraft); 4) mapping of earth's magnetic field and its direction by employment of a flux-gate as well as a spin-coil magnetometer in conjunction with a sun scanner for phase relationships; 5) fifteen subcommutated measurements of payload characteristics (i.e., critical temperature and current measurements in the payload); 6) electron density experiments by means of ground examination of carrier frequency received from UHF and VHF transmitters in the spacecraft; 7) radio-wave propagation experiments to determine effect of ionosphere by a) study of 15.5-kilocycle signals received aboard spacecraft, and b) by VHF signals transmitted from spacecraft to two earth-based receivers spaced on a 475-meter base line to measure amplitude and phase fluctuations induced by the ionosphere; 8) test of self-sustaining power supply (solar cells and batteries); 9) test of a mechanical temperature control device. Antennas: two sets of dipole aluminum rods for three transmitters and two receivers. Transmitters: a) analog telemetry, 108.06 megacycles at 500 milliwatts; b) analog telemetry, 108.09 megacycles at 500 milliwatts; c) digital primary, 378 megacycles at 5 watts. Power supply: nickel-cadmium batteries continuously charged by 8000 solar cells (1000 on each surface). Transmission Duration: last signals received October 6, 1959; 827 hours of analog and 23 hours of digital telemetry were obtained.

Test Results – On August 7, 1959, Explorer VI rose from Cape Canaveral at a northerly inclination of 48 degrees at the equator. The highly elliptical geocentric orbit achieved was even better than planned (apogee slightly

higher); the orbit-adjustment rocket was not fired. The third-stage case, 18 inches in diameter and 56 inches long, was also injected into orbit. All experiments performed flawlessly except for some difficulty during erection of paddles; some solar cells were damaged, and one paddle came to rest below its latch. This cut initial power supply to 63 percent, and the situation worsened with time. Explorer VI first detected the existence of a large ring of electrical current circulating the earth. These field deviations have been observed in widely separated regions of space. The orbit was established so that the apogee occurred on the night side of the earth (8:00 to 9:00 p.m., local satellite time), thus determining that the current flowed on the night side. Contours and irregularities in the outer region of the Van Allen radiation belt were discovered and, in fact, a complete map of the belt was obtained. The magnetometers verified the discovery by Pioneer I of fluctuations at the fringe of the geomagnetic field, which provide evidence of an interface of the magnetic field with a plasma wind originating at the sun. It was also discovered that the geomagnetic field at the lower altitudes is more regular than originally anticipated. The first complete, televised cloud-cover picture was obtained as the spacecraft passed over Mexico City. Explorer VI has made other valuable contributions to astrophysics, and some data is still being analyzed.

Participants – National Aeronautics and Space Administration, Air Force Ballistic Missile Division, Space Technology Laboratories, Inc., Douglas Aircraft Company, Aerojet-General Corporation, Allegany Ballistics Laboratory.



Explorer VI carried instruments to study particles and meteorology. It helped in the discovery of three radiation levels, a ring of electric current circling the Earth, and obtained crude cloud cover images.

Key Spacecraft Personnel		Affiliation
PM	J.C. Lindsay	NASA-GSFC
PS	C.P. Sonett	University of Arizona
CO	P.F. Glasser	TRW Systems Group
CO	G.J. Gleghorn	TRW Systems Group
CO	G.E. Mueller	NASA Headquarters
CO	A.K. Thiel	TRW Systems Group
CO	D. Latham	US Air Force
CO	J. Richards	US Air Force
CO	M.J. Stoller	Unknown
CO	J.W. Townsend	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Triple Coincidence Properties Counter	PI	J.A. Simpson	University of Chicago
	OI	C.Y. Fan	University of Arizona
	OI	P. Meyer	University of Chicago
Scintillation Counter	PI	C.P. Sonett	University of Arizona
	OI	A. Rosen	TRW Systems Group
	OI	T.A. Farley	University of California, Los Angeles
Ionization Chamber	PI	J.R. Winckler	University of Minnesota
	OI	R.A. Hoffman	NASA-GSFC
	OI	R.I. Arnoldy	University of New Hampshire
Search Coil Magnetometer	PI	C.P. Sonett	University of Arizona
	OI	E.J. Smith	NASA-JPL
	OI	D.L. Judge	University of Southern California
	OI	P.J. Coleman, Jr.	University of California, Los Angeles
Television	PI	K.D. Baker	Utah State University
Micrometeorite Detector	PI	M. Dubin	NASA-GSFC
VLF Receiver	PI	R.A. Helliwell	Stanford University
	OI	Mlodnosky	Stanford University
	OI	L.H. Rorden	DEVLCO Incorporated
Fluxgate Magnetometer	PI	P.J. Coleman, Jr.	University of California
Beacon (108 + 378 MHz)	PI	C.D. Graves	TRW Systems Group

EXPLORER VII

Launch Vehicle – The four-stage Juno II launching vehicle was made up of modified existing missile stages. The first stage was a Jupiter IRBM (liquid propellant) topped by an interstage structure replacing the nose-cone assembly. The high-speed stages were made up of 15 scaled-down Sergeant rockets (solid propellant) in the following arrangement: the second stage was assembled as a "tub" of 11 Sergeant units; the third stage was assembled as a cluster of three Sergeants nested in the center of the "tub"; and the fourth stage was a single Sergeant mounted on top of the third stage. The high-speed stages were rotated as a unit by two integral electric motors before and during launch to achieve attitude stabilization. Total height, including nose fairing, 76.7 feet; gross liftoff weight, 121,000 pounds.

Spacecraft Description – Two truncated cones joined at bases; 30 inches in height and diameter; 91.5-pound total weight. Shell composition: fiberglass and sandblasted aluminum foil.

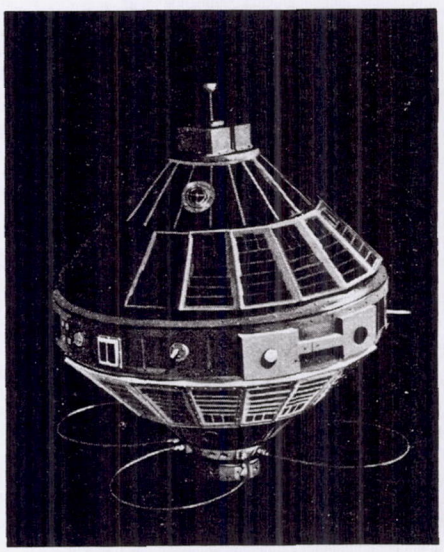
Program Objectives – To measure micrometeorite impacts; earth's radiation; Lyman-alpha X-rays; heavy primary cosmic rays; satellite temperatures. An erosion study on an exposed solar (silicon) cell on exterior of shell.

Spacecraft Payload – Antennas: a) 20-megacycle turnstile, consisting of four flexible quarter-wavelength elements that were unreeled in the spacecraft's equatorial plane; b) 108-megacycle turnstile of four rod elements. Transmitters: a) 108 megacycles at 12 milliwatts; b) 20 megacycles at 600 milliwatts; the second and third harmonics, at 40 and 60 milliwatts, are fed to the antennas at 15 and 5 milliwatts, respectively. Power supply: nickel-cadmium batteries continuously charged by solar cell attached to satellite surface.

Test Results – Explorer VII was successfully launched on October 13, 1959, from Cape Canaveral at an inclination of 50.3 degrees to the equator. Satellite went into predicted orbit, all equipment working as programmed. The expended 12-pound final stage, 6 inches in diameter and 68 inches long, also was injected into orbit.

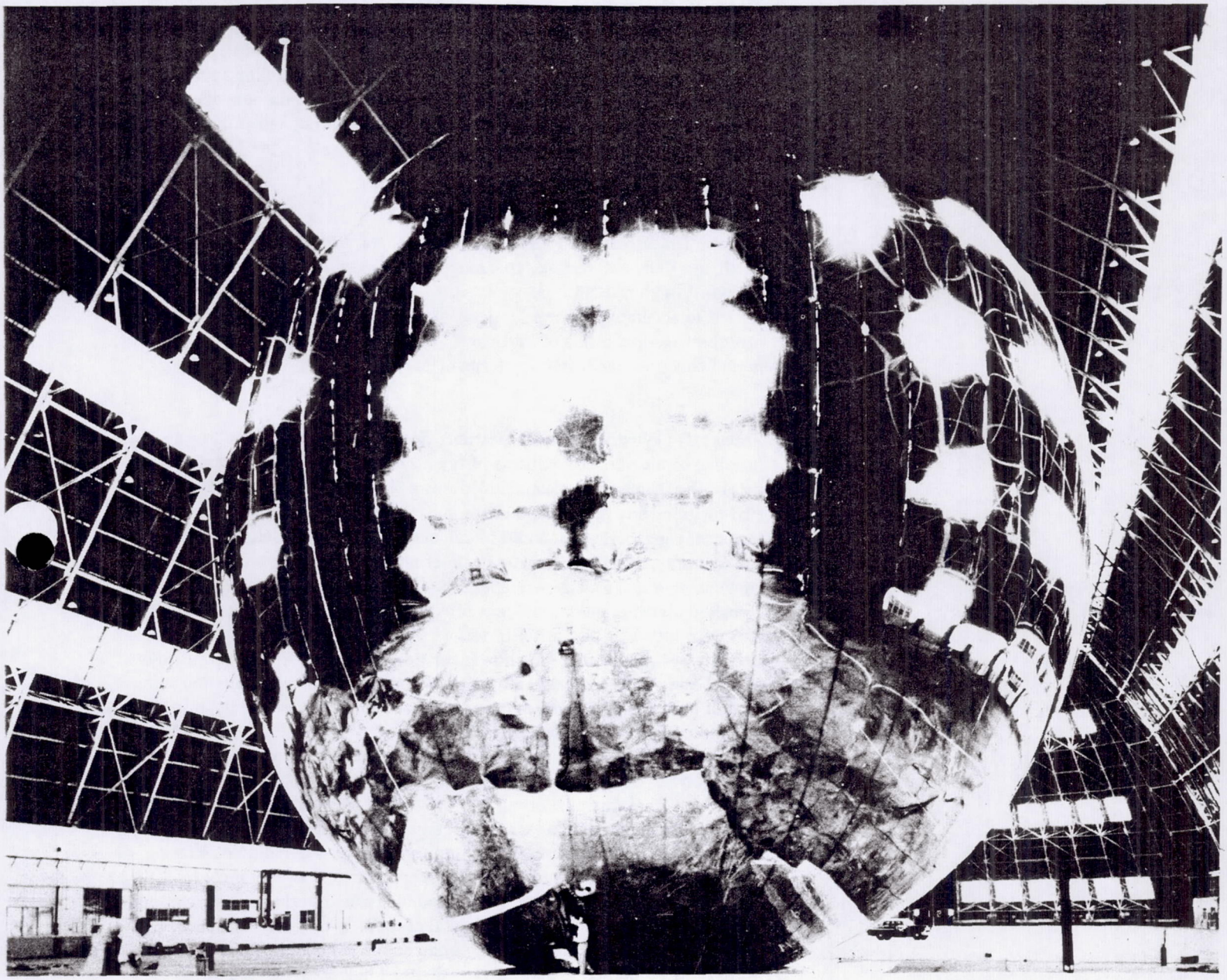
Participants – National Aeronautics and Space Administration, Jet Propulsion Laboratory, Army Ballistic Missile Agency, Chrysler Corporation, Rand Corporation.

Explorer VII provided data on energetic particles, radiation, and magnetic storms. It also recorded the first micrometeorite penetration of a sensor.



1959

1960



The 100-foot diameter Echo balloon satellite undergoes testing prior to its launch. Its aluminized mylar surface reflected radio signals from the ground. Among the experiments conducted by this project was a voice transmission of a message from then President Dwight D. Eisenhower.

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PIONEER V

Launch Vehicle – The basic three-stage Thor-Able configuration, such as used for Explorer VI, was adapted to this mission.

Spacecraft Description – Sphere, 26 inches in diameter, with four solar-cell paddles extending on arms from the equatorial plane of spacecraft, within an envelope diameter of 96 inches. There is a slightly flattened bottom at the interstage attachment. Total weight, 94.8 pounds, including approximately 43 pounds of instruments. Shell composition: aluminum alloy. Internal temperature is regulated by a paint pattern on the shell and by lithium heat sinks and infrared-emissive material on the outside of the 150-watt transmitter and its converter.

Program Objectives – To investigate interplanetary space between orbits of Earth and Venus; to test extreme long-range communications; to study methods for checking the Astronomical Unit and other astronomical distances; to accurately place an instrumented space probe into a heliocentric orbit between the orbits of Earth and Venus; to determine strength of magnetic fields near Earth and in interplanetary space.

Spacecraft Payload – Instrumentation: a search-coil magnetometer was installed to measure components of the magnetic field perpendicular to spin axis of the spacecraft. Also included was a photoelectric aspect indicator that recorded any direct looks at the sun, to obtain data from which direction of the magnetic field could be calculated and from which direction of the encountered radiation could be determined. A combination of an ionization chamber and a Geiger-Mueller tube – instruments particularly sensitive to medium energy radiation – was provided to measure the total radiation flux encountered. Also installed was a proportional counter telescope to detect very-high-energy radiation (detection threshold, 75 Mev for protons and 13 Mev for electrons) and the bremmstrahlung from electrons and gamma rays of lower energy; and a micrometeorite counter to measure the number and momentum of meteoric particles striking the probe. Eight payload performance measurements, such as internal temperature, were also subcommuted on the Telebit telemetry system. This digital system employed a 5-watt or a 150-watt transmitter, with the 5-watt transmitter acting as a driver. The information could be varied from 64 to 8 to 1 bits per second as the communication range increased. Antennas: quarter-wave dipole. Transmitters: integrated tracking, telemetry, and command system included: a receiver which delivered an offset transponded signal to the transmitter and the received command signal to a digital decoder, a 5-watt transmitter on 378 megacycles whose power on ground command could be increased to 150 watts, and a diplexer. Telemetry was digital, biphase modulated onto the carrier. The receiver, on command, operated on either a wide-band or narrow-band search mode. Power Supply: 18 volts from two packs of 14 nickel-cadmium batteries connected in series and continuously charged by 4800 boron-diffused silicon solar cells mounted on 48 aluminum modules bolted onto the four paddles.

Test Results – Pioneer V was successfully launched from Cape Canaveral on March 11, 1960, and accelerated to a burnout velocity of 36,500 feet per second (36,800 feet per second was nominal). All major program objectives were achieved. The micrometeorite counter and the aspect indicator ceased operating during launch. The heliocentric orbit was inclined 3.35 degrees to the ecliptic; the probe was expected to reach its perihelion of 74,967,000 miles on August 10, 1960 and its aphelion of 92,358,000 miles on January 13, 1961. The expended third-stage case was also in orbit, but its position was not known because of the lack of a transmitter aboard. The case was cylindrical, 18 inches in diameter, 68 inches long, and weighed approximately 12 pounds in orbit. Pioneer V established several significant "firsts" and revealed certain astrophysical phenomena that would not be satisfactorily understood until other probes traverse the same interplanetary space. Cosmic-ray measurements from this spacecraft and on earth showed that the sudden decrease in galactic cosmic rays (Forbush decrease) was of the same magnitude in space as on earth, out to distances greater than eight earth radii; these measurements helped to develop the conclusion that the Forbush decrease does not appear to depend on the earth's electromagnetic system.

Participants – Same as Explorer VI.

Key Spacecraft Personnel		Affiliation
PM	J.C. Lindsay	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Triple Coincidence Proportional Counter	PI	J.A. Simpson	University of Chicago
	OI	C.Y. Fan	University of Arizona
	OI	P. Meyer	University of Chicago
Search Coil Magnetometer	PI	E.W. Greenstadt	TRW Systems Group
	OI	D.L. Judge	University of Southern California
	OI	C.P. Sonett	University of Arizona
Ionization Chamber	PI	J.R. Winckler	University of Minnesota
	OI	R.L. Arnoldy	University of New Hampshire
	OI	R.A. Hoffman	NASA-GSFC
Micrometeorite Detectors	PI	M. Dubin	NASA-GSFC

EXPLORER (S-46)

Launch Vehicle – Juno II, gross liftoff weight was 120,000 pounds.

Spacecraft Description – Cylinder, 7 inches in diameter and 21 inches long, attached to the fourth-stage Sergeant rocket case. At the end of cylinder nearest the attachment flange, 12- by 12- by 9-inch box surrounded the payload cylinder. The exposed surfaces were covered with solar cells. Spacecraft total weight of 35.3 pounds was made up of the 12.5-pound attached case and 22.8 pounds of experimental components which included a 12.2-pound instrument pack assembly, a 7.1-pound solar-cell assembly, a 2.5-pound instrument housing, and 7 pounds of smaller components. Shell composition: aluminum alloy.

Program Objectives – To analyze a broad spectrum of electron and proton radiation energies in the radiation zones, over an extended period of time, while sweeping along a highly elliptical orbit (33,000-mile apogee); and to measure payload temperatures.

Spacecraft Payload – Instrumentation: Detector A was to count very-low energy particles (designed to bar all electrons with energies less than 200,000 electron volts, so that the detector would count protons primarily); Detector B was to count electrons with energies between 20,000 and 200,000 electron volts (operated in conjunction with Detector A); Detector C, a Geiger tube type, was to count electrons in the range of 40,000 to 90,000 electron volts; Detector D, a modified Geiger tube similar to Detector C, was to count only high-energy particles for comparison with the counting rate of Detector C; Detector E, a Geiger tube type, was to count moderately penetrating particles (similar to counter in Explorer VII). Transmitters: 108.03 megacycles at 300 milliwatts, continuously transmitting data on five channels. Power Supply: nickel-cadmium batteries continuously charged by 1184 solar cells.

Test Results – On March 23, 1960, this Explorer was launched from Cape Canaveral on a 28-degree inclination to the equator. Liftoff appeared normal, but orbit was not achieved. There was some indication of second-stage ignition, but telemetry was lost shortly after first-stage burnout. Apparently one of the upper solid-propellant stages failed to fire.

Participants – Same as Explorer VII.

TIROS I (Television Infrared Observation Satellite)

Launch Vehicle – Standard Thor-Able vehicle, such as used in launching Pioneer V, with modifications required by this mission. Liftoff weight, over 105,000 pounds; total height, 90 feet; base diameter, 8 feet.

Spacecraft Description – A "pillbox", 42 inches in diameter and 19 inches high, covered by solar cells, with three pairs of solid-propellant spin rockets mounted on baseplate. Shell composition: aluminum alloy and stainless steel. Total spacecraft weight, 270 pounds.

Program Objectives – To test experimental television techniques leading to a world-wide meteorological information system; to test sun angle and horizon sensor systems for spacecraft orientation.

Spacecraft Payload – Instrumentation: two television cameras that were identical except for lens equipment – a low-resolution camera with a f1.5 lens and a high-resolution camera with a f1.8 lens – both with 500 lines per frame and a video bandwidth of 62.5 kilocycles; a magnetic tape recorder for each camera with maximum capacity of 32 photographs taken at 30-second intervals (while out of ground-station range); two timer systems for programming future camera operations as set by a program command from either Fort Monmouth or Kaena Point stations; sensing devices for measuring spacecraft attitude, environment, and equipment operation. Antennas: four rods from baseplate for transmitters and one vertical rod from top center for receiver. Transmitters: 2-watt frequency-modulated transmitters operating on 108.0 and 108.3 megacycles at 30 milliwatts. Sun-angle sensor data was transmitted with the pictures. Both beacons transmit duplicated data on spacecraft performance. The third stage carried a tracking beacon (frequency and power not announced). Power Supply: nickel-cadmium batteries continuously charged by 9200 solar cells. Power output averaged about 19 watts.

Test Results – Tiros I was successfully launched from Cape Canaveral on April 1, 1960, into a near-circular orbit at an inclination of 48.327 degrees to the equator. The expended third stage also went into orbit near the spacecraft. The video systems relayed thousands of pictures containing cloud cover views of considerable meteorological interest. Early photographs provided new information on cloud systems, including spiral formations associated with large storms. Both direct and tape-stored picture data were satisfactory. The timer that controlled programmed operation of the high-resolution camera was inoperative from April 2 to May 10. During the period, the high-resolution camera was limited to operation by direct commands from Fort Monmouth and Kaena Point stations. Since this spacecraft was spin-stabilized, it was space oriented (not earth-oriented), and was operated only when the cameras pointed at earth and when that part of the earth's surface was in sunlight.

Tiros I, the first successful weather-study satellite, operated in a useful manner for 78 days, as compared to the expected lifetime of about three months. The low-resolution video system failed to turn off when commanded on June 17, 1960 and, as a result, the batteries serving this system lost their charge. The high-resolution system, however, remained operational, but it was considered impractical to identify narrow-angle pictures without the assistance of the wide-angle views. The low-resolution video system covered an area of roughly 800 miles on a side; the high-resolution system covered an area of about 80 miles on a side, within the other camera's view. Tiros I demonstrated that satellites can be used to survey global weather conditions and to study other surface features from space. From the time of launch, this satellite transmitted 22,952 pictures, more than 60 percent of which are good-quality cloud-cover photographs, useful to meteorological research.

Participants – National Aeronautics and Space Administration, U.S. Army Signal Research and Development Laboratory, Radio Corporation of America, Air Force Ballistic Missile Division, Space Technology Laboratories, Inc., Douglas Aircraft Company, Aerojet-General Corporation, Allegany Ballistics Laboratory, U.S. Weather Bureau, U.S. Naval Photographic Interpretation Center.

Key Spacecraft Personnel		Affiliation
PM	W.G. Stroud	NASA-GSFC
PS	H.I. Butler	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Television Transmissions	PI	H.I. Butler	NASA-GSFC

ECHO A 10

Launch Vehicle – The launching vehicle was a three-stage Thor Delta. A modified Thor IRBM was used as the first stage; a liquid-propellant rocket (7500-pound thrust) propelled the second stage; and a solid-propellant rocket of 3000-pound thrust was used as the third stage. Gross liftoff weight, approximately 112,000 pounds; total height, 92 feet; base diameter, 8 feet.

Spacecraft Description – Sphere, 100 feet in diameter when inflated, was made up of 82 separate flat gores of Mylar polyester film, covered with vapor-deposited aluminum, and weighed 132 pounds. Ten pounds of benzoid and 20 pounds of anthraquinone, carried inside the plastic sphere, was to be used for inflation. Aluminum coating, designed to provide radio-wave reflectivity, weighed 4 pounds. Total weight of plastic satellite was 166 pounds. The inflatable satellite was packed in a 26½-inch-diameter, 24-pound magnesium sphere which was to be released about 2 minutes after injection into orbit.

Spacecraft Payload – No instrumentation was carried in the plastic sphere. It was to be used as a reflector in a series of communications experiments between east- and west-coast ground stations. Transmitters: on third stage, 108.06 megacycles at 60 milliwatts. Power Supply: mercury batteries.

Test Results – The first-stage Thor lifted the Echo vehicle from Cape Canaveral before dawn on May 13, 1960, and the second stage apparently operated. During the vehicle's coast period, the attitude control jets on the second stage failed. The vehicle re-entered and was destroyed.

Participants – National Aeronautics and Space Administration, Douglas Aircraft Company, Aerojet-General Corporation, Allegany Ballistics Laboratory, G. T. Schjeldahl Company, Kaiser-Fleetwings, General Mills.



On August 12, 1960 Delta 2 launched the Echo communications satellite. It was NASA's first spaceborne communications experiment.

1960

ECHO I

Launch Vehicle – The Delta three-stage vehicle utilized the Air Force Thor IRBM, modified for this program. A 150,000-pound-thrust liquid-propellant rocket engine propels the first stage. The second stage is propelled by a liquid-propellant 7500-pound-thrust rocket engine. This stage housed the radio command guidance and the flight controller. With third stage positioned along desired orbital path, the Altair (No. 248) solid-propellant rocket power plant injected this stage and the payload into orbit with 3000 pounds of thrust for 40 seconds of firing. The magnesium payload container was separated by spring action. Gross liftoff weight, approximately 112,000 pounds; total height, 92 feet; base diameter, 8 feet.

Spacecraft Description – A 100-foot-diameter, aluminum-coated (vapor-deposited) spherical balloon inflated in orbit by expansion of residual air, benzoic acid, and anthraquinone. Plastic satellite had total weight of 166 pounds. Magnesium container weighed 24 pounds and measured 26½ inches in diameter, when assembled. The Echo container split in half 2 minutes after injection into orbit and released the folded balloon.

Spacecraft Payload – The major portion of this payload was the metal-coated balloon against which voice, pictures, and music were bounced from one border of the United States to another. Echo also carried two 11-ounce radio beacons to assist in locating and tracking the satellite. These beacons were mounted on 10-inch-diameter disks oppositely attached to balloon. Antennas: turnstile for third-stage beacon; small whip for each Echo transmitter. Transmitters: beacons, on 107.9 megacycles at 5 milliwatts; short-life beacon on expended third stage was on 108.06 megacycles at 60 milliwatts. Power Supply: five nickel/cadmium batteries charged by 70 solar cells on balloon.

Test Results – The world's first passive communications satellite, Echo I, was launched from Cape Canaveral on August 12, 1960, at an inclination of 47.28 degrees to the equator. President Eisenhower's pretaped message was the first to be bounced, going from NASA facility at Goldstone, California, to Bell Telephone's station at Holmdel, New Jersey. The first known two-way voice communication was bounced off Echo I on August 13, between Cedar Rapids, Iowa, and Richardson (near Dallas), Texas. The first reported picture transmission, via Echo I, took place August 19, from Cedar Rapids to Richardson, Texas. East-to-west transmission at 960 megacycles, and west-to-east at 2390 megacycles, were within 1 to 2 decibels of predicted signal strength. The 50-pound expended third-stage case, two metal objects, and a large piece of aluminized Mylar were also injected into orbit.

Participants – National Aeronautics and Space Administration, Douglas Aircraft Company, Rocketdyne, Aerojet-General Corporation, Allegany Ballistics Laboratory, G. T. Schjeldahl Company, Bell Telephone Laboratories, Kaiser-Fleetwings, General Mills.

Key Spacecraft Personnel	Affiliation
Robert Mackey	NASA-GSFC

PIONEER
(P-30)

Launch Vehicle – The three-stage Atlas-Able vehicle utilized a modified Atlas D ICBM (liquid-propellant, 360,000-pound-thrust) as the first stage. The second stage was a liquid-propellant adaptation of earlier Able vehicles capable of 7500-pound-thrust; the third stage was a solid-propellant modification from Able and Vanguard configurations, thrust about 3000 pounds. Liftoff weight, over 260,000 pounds; total height, 98 feet; base diameter, 10 feet.

Spacecraft Description – A 39-inch sphere with four solar-cell paddles extended on arms from the equator and rocket nozzles jutting from each pole. The thrust chamber at the payload's base was designed to increase spacecraft velocity, the chamber at the top to reduce velocity. Hydrazine-fueled, this was the first United States spacecraft with a self-contained propulsion system capable of operation many months after launch at great distances from earth. Weight, 387 pounds; shell composition, aluminum-alloy.

Program Objectives – To place a highly-instrumented probe in a moon orbit; thoroughly investigate the environment between the earth and the moon; develop a technology for controlling and maneuvering spacecraft from earth.

Spacecraft Payload – Instrumentation: 1) high-energy radiation counter; 2) ionization chamber and Geiger-Mueller tube for total radiation flux measurement, 3) scintillation counter to monitor low-energy radiation, 4) flux-gate magnetometer, search-coil magnetometer, and sun scanner for magnetic field measurement, 5) plasma probe to study the radiation effects of the solar flares, 6) scintillation spectrometer to study the earth's radiation belt as well as possible trapped radiation about the moon, 7) micrometeorite spectrometer to measure the number and momentum of meteorites striking the spacecraft, 8) temperature control system utilizing 50 four-bladed fans designed to alternately expose light and dark patches of the satellite's skin to the sun. Antennas: two sets of dipole rods. Transmitters: two 1.5 watt UHF telemetry transmitters operated on 378 megacycles. Power Supply: 8800 silicon solar cells mounted on the four paddles charged nickel-cadmium batteries.

Test Results – Atlas Able-5A was launched from Cape Canaveral on September 25, 1960. The second stage failed, however, due to a malfunction in the oxidizer system. The vehicle re-entered and was destroyed.

Major Participants – National Aeronautics and Space Administration, Air Force Ballistic Missile Division, Space Technology Laboratories, Inc., General Dynamics/Astronautics, Rocketdyne, General Electric Company, Burroughs Corporation, Aerojet-General Corporation, Allegany Ballistics Laboratory, University of Chicago, University of Minnesota.

Note: NASA's initial lunar and deep-space probes were undertaken as the Pioneer program. The first launch, Pioneer I, was launched in August, 1958. The program's most successful spacecraft, Pioneer V, established a record for radio communication in deep space – 22.5 million miles.

EXPLORER VIII

Launch Vehicle – The four-stage Juno II launching vehicle was made up of modified existing missile stages. The first stage was a liquid-propellant Jupiter IRBM topped by an interstage structure replacing the nose-cone assembly. The high-speed stages were made up of 15 scaled-down Sergeant rockets (solid-propellant) in the following arrangement: the second stage was assembled as a "tub" of 11 Sergeant units; the third stage was assembled as a cluster of three Sergeants nested in the center of the "tub"; and the fourth stage was a single Sergeant mounted on top of the third stage. These three stages were rotated as a unit by two integral electric motors before and during launch to achieve attitude stabilization. Total height, including nose fairing, 76.7 feet; liftoff weight, 121,000 pounds; base diameter, 8.75 feet.

Spacecraft Description – Two truncated cones joined at bases; 30 inches in both height and diameter; 90-pound total weight; shell composition, aluminum.

Program Objectives – Investigation of the ionosphere by direct measurement of positive ion and electron composition; collect data on the frequency momentum and energy micrometeorite impacts; establish the altitude of the base of the exosphere.

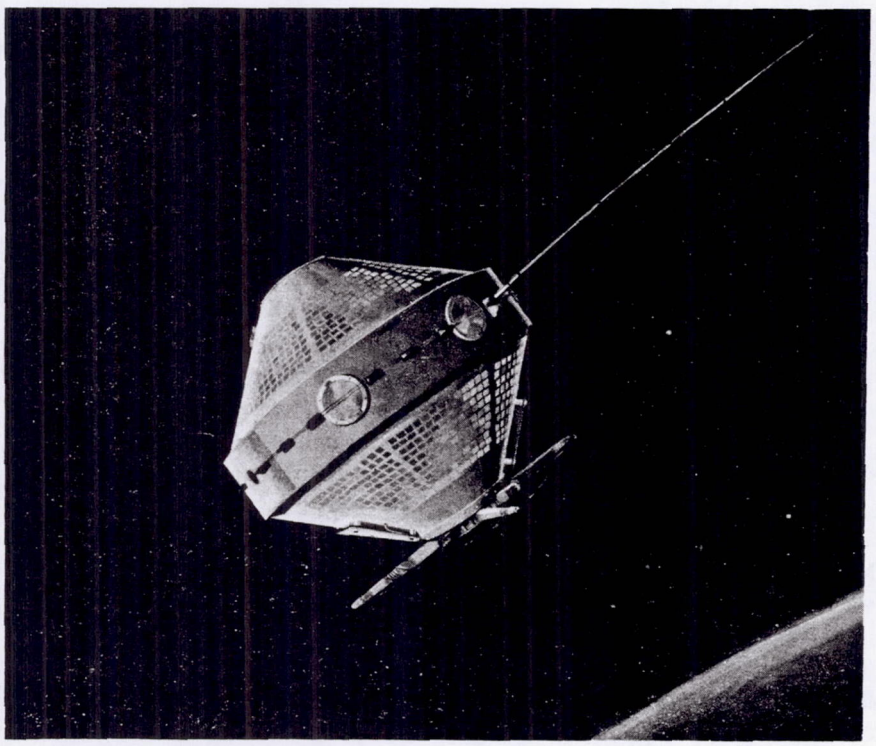
Spacecraft Payload – Instrumentation: 1) radio frequency impedance probe using a 20-foot dipole sensor, 2) single-grid ion trap, 3) four multiple-grid ion traps, 4) Langmuir probe experiment, 5) rotating-shutter electric field meter, 6) micrometeorite photomultiplier, 7) micrometeorite microphone, 8) four thermistors for temperature readings within the spacecraft and on its surface, 9) timer-separation device to expel the empty four-stage rocket, 10) two despin mechanisms to reduce the spin rate from 450 to 30 rpm. Antenna: linearly-polarized cloverleaf antenna at the base of the spacecraft. Transmitter: doubles as telemetry and tracking transmitter; on 108 megacycles at 100 milliwatts. Power Supply: eight packs of mercury batteries weighing 29.7 pounds.

Test Results – Explorer VIII was successfully launched from Cape Canaveral on November 3, 1960. An elliptical orbit, at an inclination of 50.0 degrees to the equator, was achieved with all instrumentation functioning. The spacecraft's last transmissions were received on December 27, 1960.

Major Participants – National Aeronautics and Space Administration, Army Ballistic Missile Agency, Chrysler Corporation, Sperry Rand Corporation, Rocketdyne.

Key Spacecraft Personnel		Affiliation
PM	R.E. Bourdeau	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
RI Impedance Measurements	PI	J.A. Kane	NASA-GSFC
	OI	S.J. Bauer	NASA-GSFC
Ionization Traps	PI	R.E. Bourdeau	NASA-GSFC
	OI	G.P. Serbu	NASA-GSFC
	OI	E.C. Whipple	NOAA-ERL
	OI	J.L. Donley	NASA-GSFC
Langmuir Probe	PI	O.E. Berg	NASA-GSFC
Micrometeorite Detector	PI	O.E. Berg	NASA-GSFC
Micrometeorite Detector	PI	C.W. McCracken	NASA-GSFC
Electric Field Meter	PI	J.L. Donley	NASA-GSFC
Atmospheric Drag Density	PI	L.G. Jacchia	SAO
	OI	J.R. Slowey	SAO



Explorer VIII's purpose was to study the ionosphere and confirmed existence of a helium layer in the upper atmosphere.

TIROS II

Launch Vehicle – The three-stage Delta vehicle consisted of a modified liquid-propellant Thor IRBM, a liquid rocket modified from Vanguard with radio guidance, and a spin-stabilized solid rocket. Liftoff weight, 112,000 pounds; total height, 92 feet; base diameter, 8 feet.

Spacecraft Description – Shaped like a drum, Tiros II is 42 inches in diameter and 19 inches high, with solar cells covering the top and sides. Total weight, 280 pounds; shell, aluminum/stainless steel.

Program Objectives – To test experimental television techniques and infrared equipment for a global meteorological information system; evaluate a new attitude control system utilizing the effect of the earth's magnetic field.

Spacecraft Payload – Instrumentation: two television cameras, identical except for lens equipment – a wide-angle camera with a f1.5 lens which photographs about 700 miles on each side and a narrow-angle camera with f1.8 lens covering 80 miles on a side – each with 500 lines per second and a video bandwidth of 62.5 kilocycles; a magnetic tape recorder for each camera to store up to 32 photographs each until a readout command is received from the ground station at Fort Monmouth, New Jersey, or San Nicolas Island, California; electronic clocks to control the timing of various operations – programmed from either ground station; infrared horizon sensor for attitude control; direction indicator for picture orientation; magnetic orientation control experiment; two infrared radiation experiments. Antennas: four transmitting antennas extended from the baseplate, one receiving antenna located on top. Transmitters: two 2-watt transmitters on 235 megacycles for picture transmission; one 3-watt transmitter on 237.8 megacycles for the infrared experiments; two 30-milliwatt tracking beacons on 108 and 108.3 megacycles. Power Supply: nickel-cadmium batteries charged by 9260 solar cells. Output averages about 20 watts.

Test Results – Tiros II was launched from Cape Canaveral on November 23, 1960, and was successfully injected into a near-circular orbit at an inclination of 48.5 degrees to the equator. The third-stage rocket also went into orbit near the spacecraft. As a result of a defocusing of its lens, the wide-angle camera's pictures were not of as high quality as had been obtained from Tiros I. Otherwise, the experiment was highly successful – over 75 per cent of the pictures transmitted so far have been usable. The experiment to partially control the orientation of the satellite spin axis was successful, and much valuable data has been collected through the infrared experiment.

Major Participants – National Aeronautics and Space Administration, Radio Corporation of America, United States Army Signal Research and Development Laboratories, United States Navy, Douglas Aircraft Company, United States Weather Bureau, Air Force Ballistic Missile Division, Allegany Ballistics Laboratory, Aerojet-General Corporation, Space Technology Laboratories, Inc., Bell Telephone Laboratories.

Key Spacecraft Personnel		Affiliation
PM	R.A. Stampfl	NASA-GSFC
CO	R.M. Rados	NASA-GSFC
PS	Aerospace and Meteorite Division	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Widefield Radiometer	PI	R.A. Hanel	NASA-GSFC
Scanning Radiometer	PI	J.D. Barksdale	NASA-GSFC
Television Transmissions	PI	H.I. Butler	NASA-GSFC

EXPLORER (S-56)

Launch Vehicle – The Scout vehicle was composed of four solid-propellant stages: 1) Algol, 115,000-pound-thrust, 2) Castor, a modified Sergeant with a thrust of 50,000 pounds, 3) Antares, a scaled-up version of the fourth stage with 13,600-pound-thrust, the only engine developed specifically for the Scout vehicle, 4) Altair, spin-stabilized with thrust of 3,000 pounds – served as the third stage for Able and Delta vehicles. Liftoff weight, 36,100 pounds; height, 72 feet; base diameter, 40 inches.

Spacecraft Description – A sphere, 12 feet in diameter when inflated, fabricated of Mylar polyester film and aluminum foil with a wall thickness of approximately 0.002 inch, 3400 two-inch white dots covered the sphere's surface to provide temperature balance. The sphere weighed 14 pounds and was packed in a tube 8.5 inches in diameter and 19 inches long and mounted in the nose of the fourth stage. Upon separation of the third and fourth stages, the ejection bellows, a nitrogen gas bottle under 1800 pounds per square inch pressure, was to inflate the sphere and a separation spring eject it out into its own orbit.

Program Objectives – To evaluate the Scout launch vehicle; to determine the density of the earth's atmosphere by measuring the air drag on the inflatable sphere.

Spacecraft Payload – Antenna: the two hemispheres of aluminum foil, with a Mylar equatorial gap, served as the spacecraft's antenna. Transmitter: a continuous wave crystal control transmitter on 136 megacycles at 15 milliwatts. Power Supply: 280 solar cells and batteries.

Test Results – Scout-3 was the first all-solid vehicle to be used in a U.S. orbital attempt, as well as the first orbital shot from NASA's Wallops Island facility. Launched on December 4, 1960, Scout-3's second stage failed to ignite. The vehicle impacted in the Atlantic Ocean, 80 miles east of Wallops Island.

Major Participants – National Aeronautics and Space Administration, Chance Vought Corporation, Allegany Ballistics Laboratory, Aerojet-General Corporation, Thiokol Chemical Corporation, Minneapolis-Honeywell Regulator Company, Smithsonian Astrophysical Observatory.

PIONEER (P-31)

Launch Vehicle – Same as Atlas Able-5A.

Spacecraft Description – Same as Atlas Able-5A.

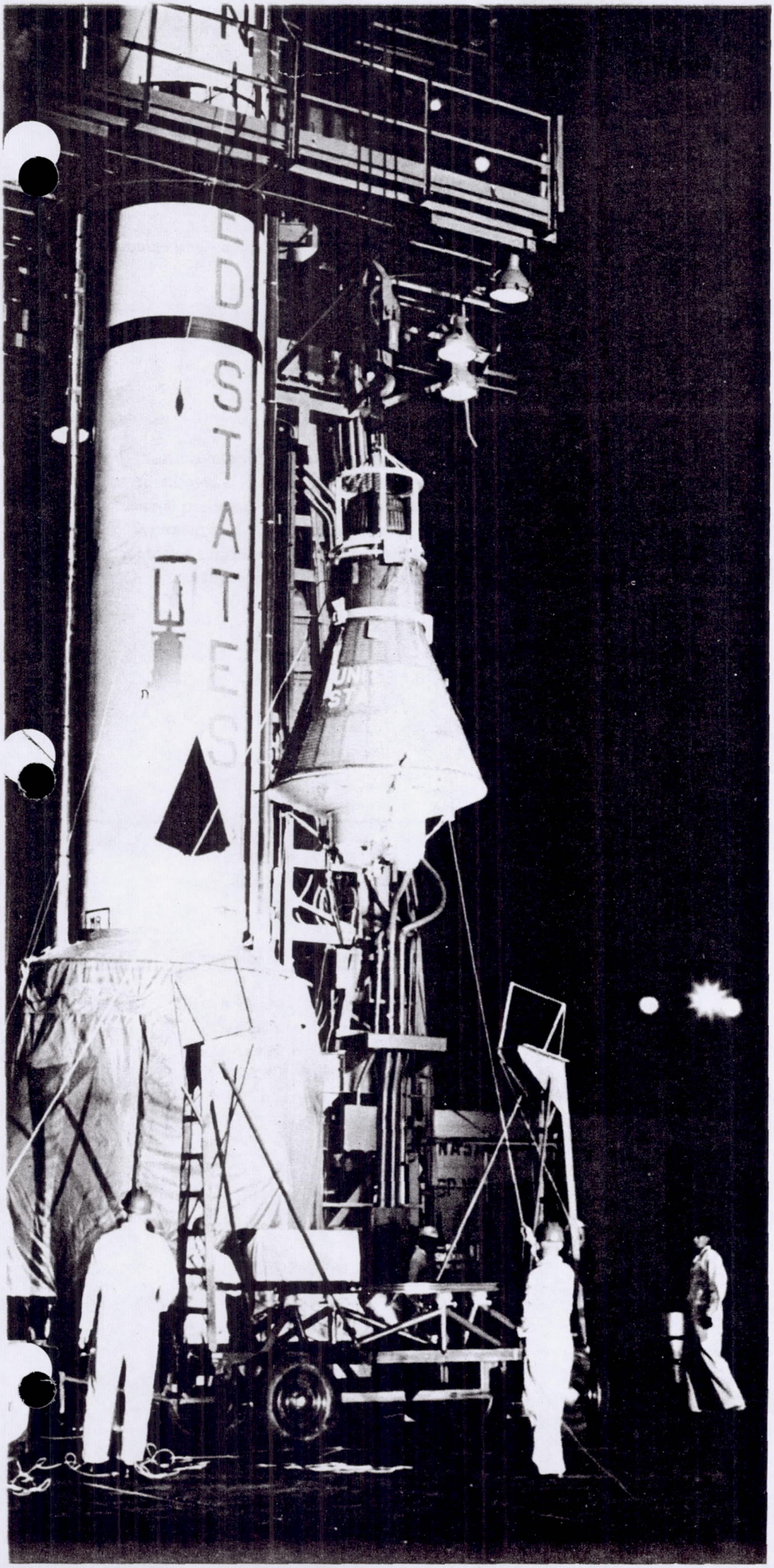
Program Objectives – Same as Atlas Able-5A.

Spacecraft Payload – Similar to Atlas Able-5A, except that a STL-designed rubidium frequency standard experiment was placed in a pod attached to the booster and a solid state detector sensitive to low energy protons added to the spacecraft.

Test Results – Atlas Able-5B was launched on December 15, 1960, from Cape Canaveral. The vehicle exploded at 40,000 feet, about 70 seconds after launch, due to a malfunction in the first stage.

Major Participation – Same as Atlas Able-5A.

1961



Freedom 7 capsule being hoisted in gantry to be mated to Redstone Booster. On May 5, 1961, it carried astronaut Alan B. Shepard, Jr. on the first 15 minute suborbital flight.

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EXPLORER IX

Launch Vehicle – A four-stage solid-propellant vehicle similar to Scout-3. Liftoff weight, 36,600 pounds; height, 72 feet; base diameter, 40 inches.

Spacecraft Description – Same as Scout-3, except for the weight – increased to 15 pounds.

Program Objectives – Same as Scout-3.

Spacecraft Payload – Same as Scout-3.

Test Results – Explorer IX was successfully launched and placed in orbit on February 16, 1961; inclination, 38.6 degrees to the equator. It was the first spacecraft placed in orbit by an all-solid rocket and the first spacecraft successfully launched from Wallops Island. The sphere's transmitter, however, broke down on the first orbit. Radar and optical tracking confirmed proper inflation of the balloon and placed its speed at 17,750 miles per hour.

Major Participants – Same as Scout-3.

Key Spacecraft Personnel		Affiliation
PM	C.W. Coffee, Jr.	NASA-LARC
PS	R.F. Fellows	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Atmospheric Drag	PI	W.J. O'Sullivan, Jr.	NASA-LARC
	OI	C.W. Coffee, Jr.	NASA-LARC
	OI	G.M. Keating	NASA-LARC
	OI	L.G. Jacchia	SAO

EXPLORER S-45

Launch Vehicle – Juno II.

Spacecraft Description – Two truncated cones joined at the bases, 30 inches in diameter, 24 inches high. Total weight, 74 pounds; shell composition, aluminum.

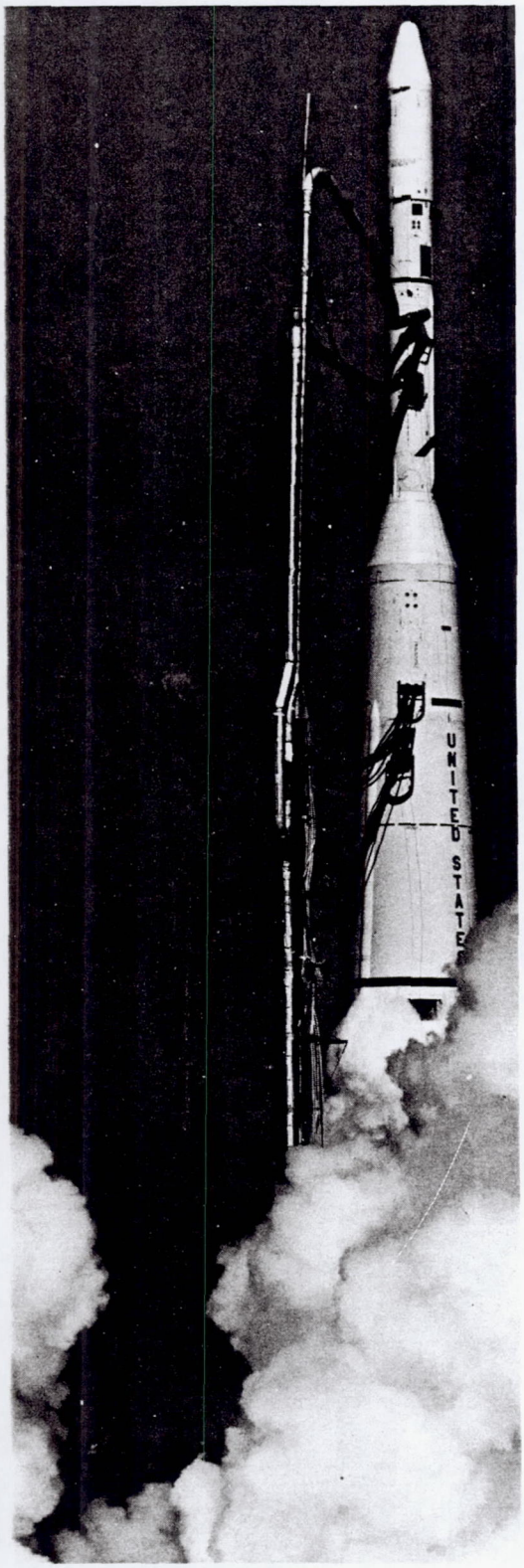
Program Objectives – Investigate the shape of the ionosphere through analysis of the satellite's transmissions by such means as change in polarization or doppler shift.

Spacecraft Payload – Antennas: a loop antenna, six feet in diameter, extended from the satellite's equator. A 19.75-inch rod was mounted in front of the satellite along the spin axis. Transmitter: six frequencies at varying levels of power were developed from a 1.0025 megacycle quartz crystal oscillator: 20.01, 40.01, 41.01, 108.02, 360.09, and 960.24 megacycles. 14 channels of telemetry data were transmitted on 108 megacycles. Power Supply: 2612 solar cells and 4 packs of nickel-cadmium batteries.

Test Results – Explorer S-45 was launched from Cape Canaveral on February 24, 1961. Orbit was not achieved; a malfunction following booster separation resulted in the loss of payload telemetry and the third and fourth stages failed to ignite.

Major Participants – National Aeronautics and Space Administration, Army Ballistic Missile Agency, Chrysler Corporation, Sperry Rand Corporation, Rocketdyne.

EXPLORER X
(P-14)



Atop the Delta 4 "rides" Explorer X launched from Cape Canaveral on March 25, 1961.

Launch Vehicle – A three-stage Thor-Delta served as the launch vehicle. A modified 150,000-pound-thrust Thor IRBM was used as the first stage, a liquid-propellant rocket (7500-pound-thrust) propelled the second stage, and a solid-propellant rocket of 3000-pound-thrust served as the third stage. Liftoff weight, 112,000 pounds; total height, 92 feet; base diameter, 8 feet.

Spacecraft Description – The spacecraft is composed of a 13-inch sphere atop a supporting tube joining the top of a 10-inch drum. Total height, 52 inches; weight, 79 pounds.

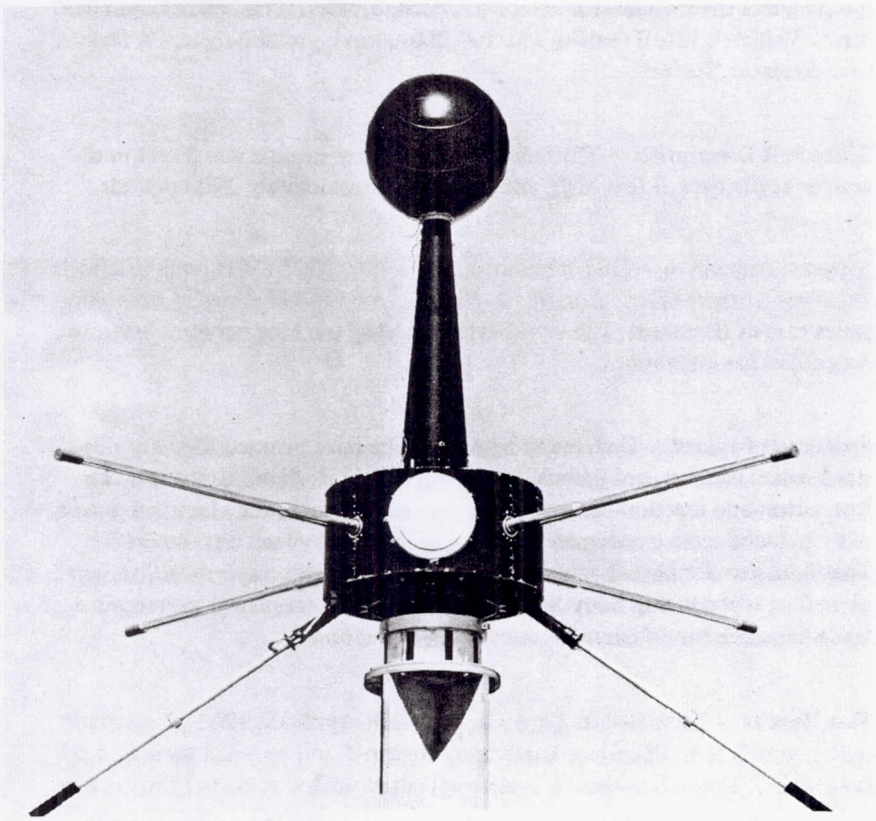
Program Objectives – To gather data on earth and interplanetary magnetic fields and the way these fields affect and are affected by solar plasma.

Spacecraft Payload – Instrumentation: 1) rubidium vapor magnetometer to measure magnetic field intensities from 0.01 to 7000 gammas, 2) two flux-gate magnetometers to determine the direction and strength of very weak magnetic fields, 3) plasma probe to make the first measurements of the direction and strength of the flow of very low energy protons from the sun, 4) optical aspect sensor. Antennas: two sets of 85-inch dipole rods. Transmitters: 108 megacycles at 5 to 6 watts. Power Supply: chemical batteries.

Test Results – Explorer X was launched from Cape Canaveral on March 25, 1961. It was successfully injected into a highly-elliptical orbit (apogee, 145,000 miles; perigee, 100 miles) at an inclination of 33.0 degrees to the equator. The spacecraft's transmissions ceased after 60 hours, some 5 hours later than expected and shortly after the apogee had been reached. Valuable information concerning solar winds, hydromagnetic shock waves, and the reaction of the earth's magnetic field to solar flares was obtained from Explorer X's experiments.

Major Participants – National Aeronautics and Space Administration, Douglas Aircraft Company, Aerojet-General Corporation, Allegany Ballistics Laboratory, Massachusetts Institute of Technology.

Arms extended, this is the way Explorer X (P-14) was to look after the nose fairing had been jettisoned. The satellite studied particles and fields in interplanetary space and near-earth reaches.



Key Spacecraft Personnel		Affiliation
PM	J.P. Heppner	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Fluxgate Magnetometer	PI	J.P. Heppner	NASA-GSFC
	OI	T.L. Skillman	NASA-GSFC
Faraday Cup	PI	H.S. Bridge	Massachusetts Institute of Technology
	OI	F. Scherb	University of Wisconsin
	OI	B. Rossi	Massachusetts Institute of Technology
Solar Aspect Sensor	PI	J.S. Albus	NASA-GSFC

MERCURY ATLAS III (MA-3)

Launch Vehicle – The liquid-propellant Atlas D ICBM, with slight modifications, was employed. Modification included a heavier skin at the forward end of the liquid oxygen tank, alterations to guidance and flight programmer systems, and the inclusion of an abort-sensing system. The 360,000-pound-thrust Vehicle's liftoff weight was 260,000 pounds; total height, 88 feet; base diameter, 10 feet.

Spacecraft Description – The bell-shaped Mercury capsule was 6 feet in diameter at the base, 9 feet high, and weighed approximately 2000 pounds.

Program Objectives – This unmanned shot was to place the capsule in a single earth orbit, then return it to earth within a preplanned recovery area 300 miles east of Bermuda. The world-wide Mercury tracking network was also scheduled for evaluation.

Spacecraft Payload – Systems to be used in the later manned Mercury missions which were aboard included: communications, stabilization and control, automatic reaction control, environmental control, and electrical power. Also included were a crewman simulator and two playback tape recorders. The simulator duplicated an astronaut's circulatory and respiratory functions, as well as reproducing body heat. The tape recorders played prerecorded voice messages for communication system evaluation.

Test Results – Launched at Cape Canaveral on April 25, 1961, the vehicle failed to roll to a 70-degree heading after liftoff and to pitch over into its trajectory. The abort-sensing system activated escape rockets prior to the booster's destruction by the range safety officer at 16,400 feet. The capsule coasted up to 24,000 feet, deployed its parachutes, and landed in the Atlantic Ocean 2000 yards north of the launch pad.

Major Participants – National Aeronautics and Space Administration, McDonnell Aircraft Company, Air Force Space Systems Division, U.S. Navy, Aerospace Corporation, General Dynamics/Astronautics, Rocketdyne, Western Electric Company, Minneapolis-Honeywell Regulator Company, Collins Radio, Garrett Corporation, Radioplane, Perkin-Elmer Corporation, Bell Aerospace Corporation.

Note: This report includes selected highlights of the early days of the U.S. man-in-space program. For detailed descriptions numerous excellent NASA publications and reports are available.

NASA scheduled its first manned orbital flight for late 1961. Extensive unmanned orbital and manned ballistic launches were programmed prior to that time.

EXPLORER XI

Launch Vehicle – Juno II was used, the same as Explorer VIII.

Spacecraft Description – Explorer XI consisted of three sections: 1) an octagonal aluminum box containing the S-15 gamma ray "telescope" 12 inches in diameter and 23.5 inches long with a 17-inch-diameter plate fitted on top, 2) an aluminum instrument column 20.5 inches long, 6 inches in diameter, 3) the 44-inch-long fourth-stage Sergeant rocket. Total weight, 82 pounds.

Program Objectives – To detect high energy gamma rays from cosmic sources and map their distribution in the sky. This was the first attempt at this kind of space astronomy from a satellite.

Spacecraft Payload – Instrumentation: the gamma ray telescope consisted of a plastic scintillator covering the top and sides, a sandwich of crystal layers composed of sodium iodide and cesium iodide, and a Cerenkov detector. A micrometeorite shield, temperature sensor, sun and earth sensor, and a tape recorder are also carried. A damping mechanism in the fourth-stage rocket case held the spacecraft's tumbling action to about ten revolutions per minute. Antennas: a four-leaf loop antenna projected from the instrument column for tape recording readout transmissions; the entire spacecraft served as the antenna for the tracking and continuous data transmitter. Transmitters: a) taped data transmitter on 107.97 megacycles at 125 milliwatts, b) tracking transmitter on 108.06 megacycles at 20-25 milliwatts. Power Supply: solar cells and 12 nickel-cadmium batteries.

Test Results – Explorer XI was launched from Cape Canaveral on April 27, 1961. It was successfully placed in an elliptical orbit at an inclination of 28.8 degrees to the equator. All payload systems functioned as planned.

Major Participants – National Aeronautics and Space Administration, Army Ballistic Missile Agency, Chrysler Corporation, Sperry Rand Corporation, Rocketdyne, Massachusetts Institute of Technology.

Key Spacecraft Personnel		Affiliation
PS	J.E. Kupperian, Jr.	NASA-GSFC

Experiment	Experiment Personnel	Affiliation
Gamma Ray Telescope	PI W.I. Kraushaar	University of Wisconsin
	OI G. W. Clark	Massachusetts Institute of Technology

FREEDOM 7 (Mercury Redstone 3)

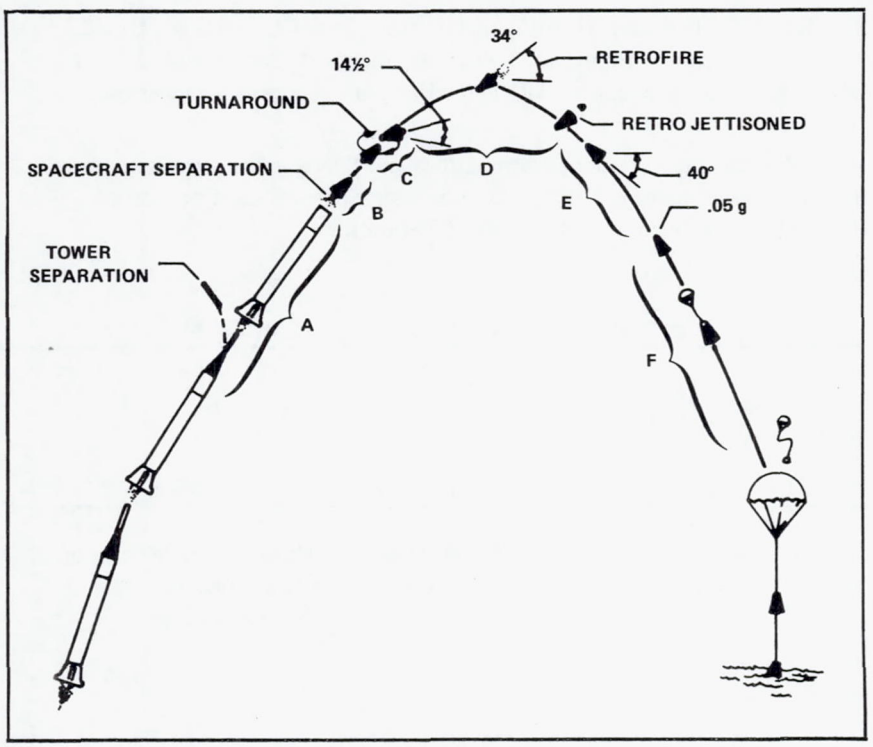
Launch Vehicle – Mercury Redstone 3.

Spacecraft Description – Mercury capsule, 6 feet in diameter, 9 feet high.

Project Objective – Successfully launch and recover manned spacecraft; evaluate performance of man and spacecraft; evaluate astronaut and the operational suitability of spacecraft and support systems.

Spacecraft Payload – Astronaut Alan B. Shepard and "man-rated" space support systems.

Test Results – The Freedom 7/Mercury Redstone 3 (MR-3) mission, the first manned space flight by the United States, was successfully accomplished on May 5, 1961, from the Cape Canaveral launch site. Astronaut Alan B. Shepard Jr. was the pilot. The space vehicle was composed of production spacecraft 7 and a Mercury Redstone launch vehicle. Analyses of the results of the mission showed that Astronaut Shepard satisfactorily performed his assigned tasks during all phases of the flight. Likewise, launch vehicle and spacecraft systems performed as planned. The spacecraft achieved an altitude of about 101 nautical miles and was in weightless flight for slightly over 5 minutes. Postflight examination of Astronaut Shepard and inspection of the spacecraft showed both to be in excellent condition. A helicopter pickup was made of the spacecraft after the pilot had made his egress from the side hatch of the spacecraft and had been hoisted aboard the helicopter. The pilot and the spacecraft were landed aboard an aircraft carrier 11 minutes after spacecraft landing, and the spacecraft was brought back to the launching site the morning after the flight.



Freedom 7/Mercury Redstone 3 flight profile.

EXPLORER S-45 a

Launch Vehicle – Same as Explorer VIII.

Spacecraft Description – Two truncated cones joined at the bases, 30 inches in diameter, 24 inches high. Total weight, 74 pounds; shell composition, aluminum.

Program Objectives – To investigate the shape of the ionosphere – to learn where there are concentrations of electrons, where the ionosphere's profile has peaks or valleys in its structure.

Spacecraft Payload – Antennas: a loop antenna, six feet in diameter, extended from the satellite's equator. A 19.75-inch rod was mounted in front of the satellite along the spin axis. Transmitter: six frequencies at varying levels of power were developed from a 1.0025 megacycle quartz crystal oscillator: 20.01, 40.01, 41.01, 108.02, 360.09, and 960.24 megacycles. Fourteen channels of telemetry data were transmitted on 108 megacycles. Power Supply: 2612 solar cells and 4 packs of nickel-cadmium batteries.

Test Results – Explorer S-45 a was unsuccessfully launched from Cape Canaveral on May 24, 1961. The second attempt to orbit a S-45 ionosphere beacon, it failed due to a malfunction in the second-stage ignition system.

Major Participants – National Aeronautics and Space Administration, Army Ballistic Missile Agency, Chrysler Corporation, Sperry Rand Corporation, Rocketdyne.

EXPLORER S-55
(Meteoroid Satellite A)

Launch Vehicle – The Scout vehicle was composed of four solid-propellant stages; 1) Algol, 103,000-pound-thrust, 2) Castor, 62,000-pound-thrust, 3) Antares, 13,600-pound-thrust, and 4) Altair, 2800-pound-thrust – also used for the third stage on Able and Delta vehicles. Liftoff weight, 36,600 pounds; height, 72 feet; base diameter, 40 inches.

Spacecraft Description – The payload was wrapped around the fourth stage, plus an extension on the rocket's nose. Diameter, 24 inches; length, 76 inches; weight, 187 pounds.

Program Objectives – Evaluate the Scout launch vehicle and its guidance system; investigate the nature of micrometeoroids and their effects on space flight.

Spacecraft Payload – Experiments: 1) 160 half-cylinder cells made of varying thicknesses of beryllium copper and pressurized with nitrogen, 2) 60 triangular foil gauge detectors mounted under stainless steel skin samples, 3) 46 copper wire grids wound on melamine cards, 4) two cadmium-sulfide cells mounted in aluminized glass flasks, 5) piezoelectric crystal impact detecting transducers, 6) five groups of solar cells with various protective coverings. Antennas: four whip antennas extending from the nose section. Transmitters: two separate telemetry transmitters operated by command for a maximum of one minute on 136.86 and 136.20 megacycles. Power Supply: solar cells mounted on the side of the nose section and batteries.

Test Results – Explorer S-55 was launched from Wallops Island on June 30, 1961. The Scout vehicle reached an altitude of about 70 miles, then fell into the Atlantic Ocean when its third stage failed to ignite.

Major Participants – NASA Langley Research Center, payload experiments, payload integration, Scout technical direction; NASA Lewis Research Center and Goddard Space Flight Center, payload experiments; Ling-Temco-Vought, Inc., Scout prime contractor; Aerojet-General Corporation, first stage propulsion; Thiokol Chemical Corporation, second stage propulsion; Allegany Ballistics Laboratory, third and fourth stage propulsion; Minneapolis-Honeywell Regulator Company, Scout guidance system.

LIBERTY BELL 7 (Mercury Redstone 4)

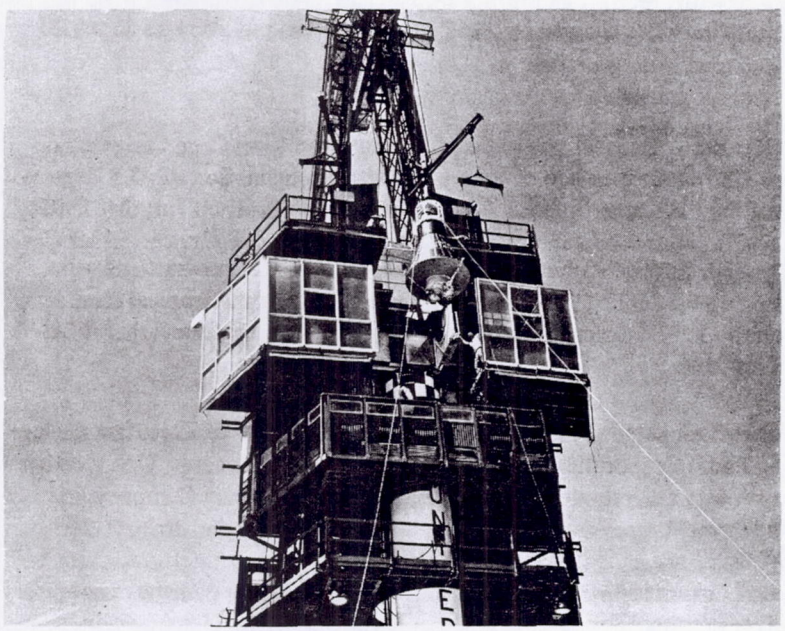
Launch Vehicle – Mercury Redstone 4.

Spacecraft Description – Mercury capsule, approximately 6 feet in diameter, 9 feet high.

Project Objective – Manned suborbital flight. Evaluate performance of astronaut and all support systems.

Spacecraft Payload – Astronaut Virgil I. Grissom.

Test Results – The Liberty Bell 7/Mercury Redstone 4 (MR-4) flight was successfully made on July 21, 1961, from the Cape Canaveral launch site. Astronaut Virgil I. Grissom was the pilot. The space vehicle was made up of the 11th production spacecraft and a Mercury Redstone launch vehicle essentially identical to the one used for MR–3 mission. The spacecraft on this mission was somewhat different from spacecraft 7, in that, for the first time, a manned spacecraft had a large top window, a side hatch to be opened by an explosive charge, and a modified instrument panel. The spacecraft achieved a maximum altitude of about 103 nautical miles, with a period of weightlessness of about 5 minutes. The flight was successful. After landing, premature and unexplained actuation of the spacecraft explosive side hatch resulted in an emergency situation in which the spacecraft was lost but the pilot was rescued from the surface of the water. Analyses of the data from the flight and debriefing by the astronaut indicated that, in general, the spacecraft systems performed as planned, except for the action of the spacecraft hatch. An intensive investigation of the hatch actuation resulted in a change in operational procedures. No fault was found in the explosive device.



Virgil I. Grissom made a 16-minute suborbital flight aboard Liberty Bell 7 on July 21, 1961. Here, the capsule is being placed atop a Mercury Redstone booster.

1961

TIROS III

Launch Vehicle – The three-stage Delta consisted of a modified Thor (150,000-pound-thrust), a liquid rocket modified from Vanguard (7500-pound-thrust), and a spin-stabilized solid rocket also modified from the Vanguard vehicle (3000-pound-thrust). Liftoff weight, approximately 112,000 pounds; total height, 92 feet; base diameter, 8 feet.

Spacecraft Description – Shaped like a drum – 42-inch diameter, 19 inches high; the top and sides covered with solar cells; weight, 285 pounds.

Program Objectives – Continued development of a meteorological satellite system; provide useful cloud cover photographs for operational weather forecasting; obtain infrared measurements of the solar energy absorbed, reflected, and emitted by the earth.

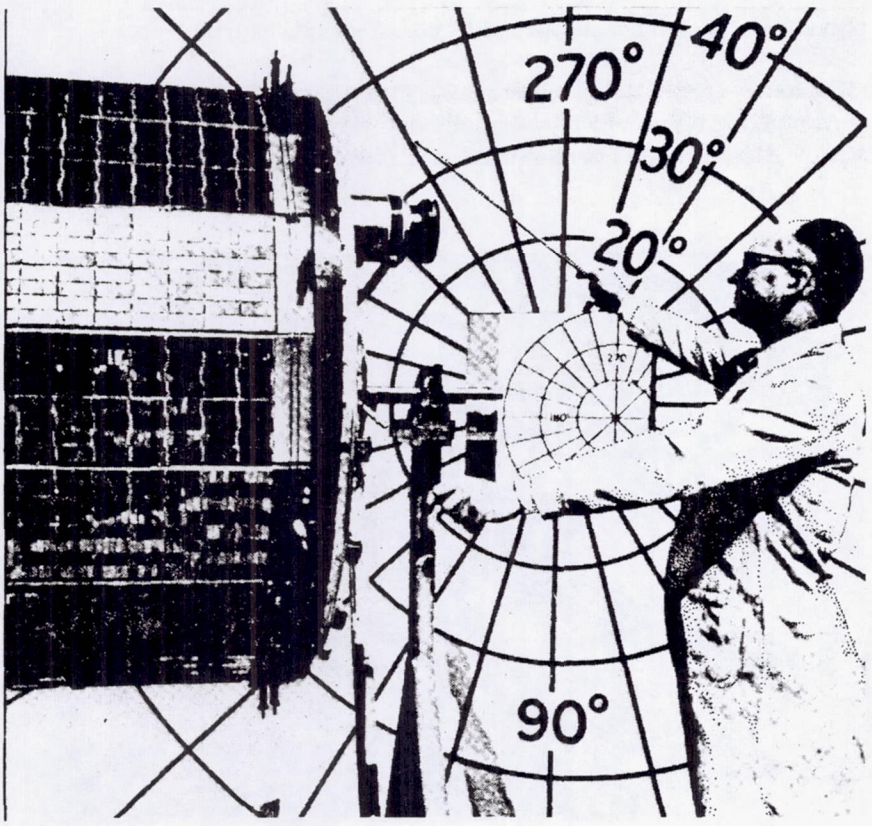
Spacecraft Payload – Three major changes from previous Tiros models: use of a second wide-angle television camera instead of the earlier narrow-angle type, a new infrared experiment, and improved remote control programmers. Instrumentation: two wide-angle vidicon cameras, each with a one-half inch f1.5 lens designed to photograph about 700 miles on a side; a magnetic tape recorder for each camera to store up to 32 photographs each until a readout command is received; electronic clocks to control the timing of various operations – programmed from either ground station; infrared horizon sensor; solar cell direction indicators for picture orientation; magnetic orientation control system; three infrared radiation experiments, one scanning and two non-scanning. Antennas: four transmitting antennas extending from the baseplate, one receiving antenna located on top. Transmitters: two 2-watt transmitters on 235 megacycles for picture transmission; one 3-watt transmitter on 237.8 megacycles for the infrared experiments; two 30-milliwatt tracking beacons on 108 and 108.3 megacycles. Power Supply: nickel-cadmium batteries charged by 9260 solar cells. Output averages about 20 watts.

Test Results – Tiros III was successfully launched from Cape Canaveral on July 12, 1961, into a near-circular orbit with an inclination of 47.8 degrees. One of the two cameras failed following the 107th orbit on July 24, 1961; as a result, the second camera was pressed into full-time service. Otherwise, photograph quality has been excellent and the infrared experiments were yielding useful data. Tiros III photographed many of the tropical storms during the 1961 hurricane season and was credited with discovering Hurricane Esther.

Major Participants – NASA Goddard Space Flight Center, executive management; Radio Corporation of America, Tiros prime contractor; U.S. Weather Bureau, data analysis and distribution; Barnes Engineering Company and University of Wisconsin, Tiros radiation detectors; Douglas Aircraft Company, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General Corporation, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.

Key Spacecraft Personnel		Affiliation
PM	R.M. Rados	NASA-GSFC
PS	Aerospace and Meteorology Division	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Omni Radiometer	PI	V.E. Suomi	University of Wisconsin
Widefield Radiometer	PI	R.A. Hanel	NASA-GSFC
Scanning Radiometer	PI	R.M. Rados	NASA-GSFC
	OI	J.D. Barksdale	NASA-GSFC
Television Experiment	PI	Ness Staff	NOAA-NESS
	PI	R.M. Rados	NASA-GSFC



Calibration of Tiros weather satellite. NASA's first generation meteorological spacecraft.

1961

EXPLORER XII

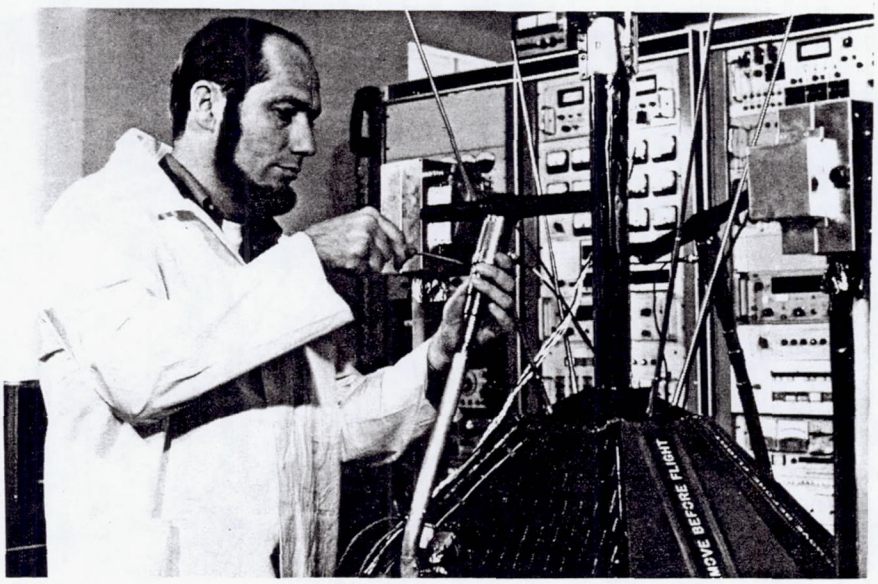
Launch Vehicle – The three-stage Delta; with the first stage a modified Thor (150,000-pound-thrust), a liquid-propellant rocket adapted from Vanguard serving as the second stage (7500-pound-thrust), and a spin-stabilized solid rocket also modified from the Vanguard vehicle as the third stage (3000-pound-thrust). Liftoff weight, about 112,000 pounds; total height, 92 feet; base diameter, 8 feet.

Spacecraft Description – Basically a truncated cone attached to an octagonal platform, 19 inches high and 26.2 inches across the flats of the octagon. The platform, 5.5 inches thick and fabricated of nylon honeycomb and fiberglass with an aluminum cover, housed most of the electronic equipment and experiments. Four solar paddles and a 32-inch column supporting a magnetometer package extended from the platform. Total spacecraft weight, 83 pounds.

Program Objectives – Explorer XII was the first of a series of four spacecraft designed to investigate the solar winds, interplanetary magnetic fields, distant regions of the earth's magnetic field, and energetic particles in interplanetary space and the Van Allen belts.

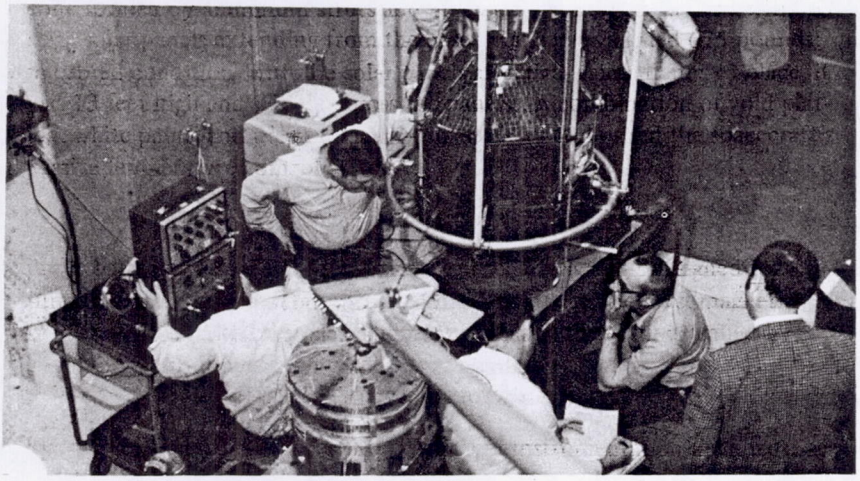
Spacecraft Payload – Experiments: 1) proton analyzer, 2) fluxgate magnetometer, 3) trapped particle radiation device, 4) cosmic ray indicator, 5) ion electron indicator, 6) four silicon solar cell samples. A photocell optical sensing system provided data on the spacecraft's orientation in space. One two-watt transmitter on 136.02 megacycles was onboard. The power supply consisted of 5600 solar cells and 13 silver-cadmium batteries.

Test Results – Explorer XII was successfully launched from Cape Canaveral on August 16, 1961, into a highly-elliptical orbit with an inclination of 33.3 degrees. The spacecraft has transmitted a mass of usable information.



Explorer XII was the first of a series of four spacecraft designed to investigate the solar winds, interplanetary magnetic fields, distant regions of the Earth's magnetic field, and energetic particles in interplanetary space and the Van Allen Belts.

Major Participants – NASA Goddard Space Flight Center, executive management, payload experiments; NASA Ames Research Center, University of New Hampshire, State University of Iowa, payload experiments; Douglas Aircraft Company, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General Corporation, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.



The Explorer XII team at work. Explorer XII was to study particles and fields; it identified the Van Allen Belts as a magnetosphere.

Key Spacecraft Personnel		Affiliation
PM	P. Butler	NASA-GSFC
PS	F.B. McDonald	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Electrostatic Analyzer	PI	M. Bader	NASA-ARC
3-Axis Flux Magnetometer	PI	L.J. Cahill, Jr.	University of Minnesota
Charged Particle	PI	J.A. Van Allen	University of Iowa
	OI	L.A. Frank	University of Iowa
	OI	B.J. O'Brien	Department of Environmental Protection
	OI	C.D. Laughlin	McDonald Observatory
	OI	J.W. Freeman	Rice Univeristy
C.R. Scint + Dbl. Scintillator Telemeter	PI	F.B. McDonald	NASA-GSFC
D.1-10MeV Prot + Elec Scintillator	PI	L.R. Davis	NASA-GSFC
	OI	J.M. Williamson	NASA-GSFC
Solar Cell Damage	PI	G.W. Longanecker	NASA-GSFC

RANGER I

Launch Vehicle – The Atlas-Agena, with a modified Atlas D (360,000-pound-thrust) serving as the first stage and the Agena B (15,000-pound-thrust) as the second stage. Approximate liftoff weight, 275,000 pounds; total height, 102 feet; base diameter, 10 feet.

Spacecraft Description – Ranger I was basically a cone formed by aluminum struts and braces with a hexagonal base and two large wing-like solar panels extending from the base. The spacecraft weighed 675 pounds and had a base diameter of 5 feet; in orbital condition it was 13 feet high and measured 17 feet across the solar panels. A combination of gold plating, white paint, and polished aluminum comprised the spacecraft's passive temperature control system.

Program Objectives – The first Ranger mission was primarily designed to flight test the spacecraft in a 685,000-mile perigee, 37,500-mile apogee orbit as a prelude to lunar missions beginning with Ranger III. Several scientific experiments designed to investigate cosmic rays, magnetic fields, and energetic particles in deep space were also carried.

Spacecraft Payload – Experiments: 1) solar corpuscular detector, 2) medium-range particle detectors, 3) cosmic ray ionization chamber, 4) triple-coincidence cosmic ray telescopes, 5) rubidium vapor magnetometer, 6) solar X-ray scintillation detectors, 7) Lyman alpha telescope, 8) cosmic dust detectors, 9) calibrated solar cells, 10) engineering friction experiment. Instrumentation: spacecraft controller – a solid-state timing device, sun and earth sensors, pitch and roll jets. Antennas: omni-directional antenna, high-gain directional antenna. Transmitters: one 0.25-watt transmitter on 960.1 megacycles, one 3-watt transmitter on 960.05 megacycles. Power Supply: 8680 solar cells on the two panels, 125-pound silver-zinc battery, individual batteries for some experiments.

Test Results – The Agena B/Ranger I was launched from Cape Canaveral on August 23, 1961, into a parking orbit. The first U.S. attempt to launch a spacecraft from an orbiting platform was only a limited success, however, as the Agena B apparently failed to restart in an attempt to provide sufficient escape velocity for Ranger I. As a result, when Ranger I separated it went into a low earth orbit nearby with an inclination of 32.90 degrees. Ranger I re-entered on August 30, 1961. The primary flight test objective was largely accomplished; however, only limited data was gained from the scientific experiments.

Major Participants – NASA Jet Propulsion Laboratory, California Institute of Technology, spacecraft design, integration, and tracking; NASA Marshall Space Flight Center, launch vehicle meanagement; General Dynamics/Astronautics, Atlas prime contractor; Rocketdyne, Atlas propulsion; General Electric Company and Burroughs Corporation, Atlas guidance system; Lockheed Missiles and Space Company, Agena prime contractor; Bell Aero-

space, Agena propulsion; NASA Space Task Group, executive management; McDonnell Aircraft Corporation, payload instrumentation; USAF Missile Test Center, launch management; Aeronutronic, Scout prime contractor; Aerojet-General Corporation, first stage propulsion; Thiokol Chemical Corporation, second stage propulsion; Allegany Ballistics Laboratory, third and fourth stage propulsion; Minneapolis-Honeywell Regulator Company, Scout guidance system.

Key Spacecraft Personnel		Affiliation
PM	James D. Burke	JPL
PS	Marcia M. Neugebauer	JPL
MG	Benjamin Milwitzky	JPL

Experiment	Experiment Personnel		Affiliation
Lyman Alpha Telescope	PI	T.A. Chubb	US Naval Research Laboratory
Magnetometer	PI	J.P. Heppner	NASA-GSFC
	OI	J.D. Stolarik	NASA-GSFC
	OI	D.F. Jones	Brigham Young University
	OI	M.B. Gumpel	NASA-JPL
Electrostatic Analyzer	PI	M.M. Neugebauer	NASA-JPL
	OI	C.W. Snyder	NASA-JPL
	OI	C.S. Josias	NASA-JPL
	OI	J.L. Lawrence, Jr.	NASA-JPL
Charged Particle Experiment	PI	J.A. Van Allen	University of Iowa
	OI	M.M. Neugebauer	NASA-JPL
	OI	C.W. Snyder	NASA-JPL
	OI	J.D. Allen	NASA-JPL
	OI	L.A. Frank	University of Iowa
Charged Particle Experiment	PI	J.A. Simpson	University of Chicago
	OI	C.Y. Fan	University of Arizona
	OI	P. Neyer	University of Chicago
Cosmic Ray Detectors	PI	V.H. Neher	California Institute of Technology
	OI	H.R. Anderson	Rice University
	OI	W.S. McDonald	NASA-JPL
Cosmic Dust Detector	PI	W.M. Alexander	Baylor University
	OI	M.M. Neugebauer	NASA-JPL
	OI	E.S. McMillan	NASA-JPL
Scintillation Counters	PI	T.G. Northrop	NASA-GSFC

EXPLORER XIII

Launch Vehicle – Same as Explorer S-55.

Spacecraft Description – Same as Explorer S-55.

Program Objectives – Continued evaluation of the Scout launch vehicle – the first entirely solid-propellant booster; the secondary flight mission was the orbit of the S-55 payload to investigate micrometeoroid impact and penetration.

Spacecraft Payload – Same as Explorer S-55.

Test Results – Explorer XIII was successfully launched from Wallops Island on August 25, 1961; inclination was 36.42 degrees. The initial orbit was much lower than the originally calculated apogee of 174 miles, and the spacecraft re-entered on August 28. Considerable data was obtained, however, during Explorer XIII's short life.

Major Participants – NASA Langley Research Center, payload experiments, payload integration, Scout technical direction; NASA Lewis Research Center and Goddard Space Flight Center, payload experiments; Ling-Temco-Vought, Inc., Scout prime contractor; Aerojet-General Corporation, first stage propulsion; Thiokol Corporation, second stage propulsion, Allegany Ballistics Laboratory, third and fourth stage propulsion; Minneapolis-Honeywell Regulator Company, Scout guidance system.

Key Spacecraft Personnel		Affiliation
PM	C.T. D'Aiutolo	Unknown

Experiment	Experiment Personnel		Affiliation
Pressurized Cell	PI	C.A. Gurtler	NASA-LARC
Copper Wire Card	PI	L. Secretan	NASA-LARC
Cadmium Sulphide Cell	PI	L. Secretan	NASA-LARC
Impact Detection	PI	A.G. Beswick	NASA-LARC
Grid Detectors	PI	Unknown	Unknown

MERCURY-ATLAS IV

Launch Vehicle – The liquid-propellant Atlas D (360,000-pound-thrust), with slight modifications, was employed. Modifications included a heavier skin at the forward end of the liquid oxygen tank, alterations to guidance and programmer systems, and the inclusion of an abort-sensing system. The vehicle's liftoff weight was 260,000 pounds; total height including escape system, 93 feet; base diameter, 10 feet.

Spacecraft Description – The bell-shaped capsule was 6 feet in diameter at the base, 9 feet high, and weighed approximately 2700 pounds in orbital condition.

Program Objectives – Similar to the unsuccessful Mercury-Atlas III – in fact the same capsule was used: an unmanned capsule was to be placed in a single orbit, then returned to earth in a recovery area 200 miles east of Bermuda. The world-wide Mercury tracking network was also scheduled for evaluation.

Spacecraft Payload – The standard Mercury communication, stabilization and control, reaction control, life support, and electrical power systems were on board. In addition, the spacecraft contained a crewman simulator and two playback tape recorders. The simulator duplicated an astronaut's circulatory and respiratory functions, as well as reproducing body heat. The tape recorders played pre-recorded voice transmissions for communication system evaluation. Three cameras and special instrumentation to record vibration, accelerations, and temperature were also on board. The spacecraft, one of the earlier models produced, did not have a landing bag or jettisonable hatch.

Test Results – Mercury-Atlas IV was successfully launched from Cape Canaveral on September 13, 1961; inclination was 32.57 degrees. After one orbit the spacecraft's timer triggered the retrorockets. The capsule splashed down 161 miles east of Bermuda and was picked up by the USS Decatur. The flight was termed highly successful with only three deviations from normal: a leak in the oxygen system, loss of voice contact over Australia, and the failure of an inverter in the environmental control system's power supply.

Major Participants – NASA Space Task Group, executive management; McDonnell Aircraft Company, capsule prime contractor; Minneapolis-Honeywell Regulator Company, capsule stabilization and control system; Collins Radio, capsule instrumentation and communication systems; Garrett Corporation, capsule environmental control system; Radioplane, capsule recovery system; Lockheed Propulsion Company, capsule escape rocket; USAF Space Systems Division, Atlas executive and launch management; General Dynamics/Astronautics, Atlas prime contractor; Aerospace Corporation, Atlas systems engineering and technical direction; Rocketdyne, Atlas propulsion; General Electric Company and Burroughs Corporation, Atlas guidance system; Western Electric Company, tracking network prime contractor; U.S. Navy, recovery task force management.

MERCURY-SCOUT I

Launch Vehicle – Scout booster with four solid-propellant stages: 1) Algol, 103,000-pound-thrust, 2) Castor, 62,000-pound-thrust, 3) Antares, 13,600-pound-thrust, and 4) Altair, 2800-pound-thrust. Liftoff weight, 36,600 pounds; height, 72 feet; base diameter, 40 inches.

Spacecraft Description – The payload was contained in a 12 by 12 by 17 inch package attached to the front end of the fourth stage, giving the spacecraft a cigar-shaped configuration 89 inches long: total weight, 214 pounds.

Program Objectives – A three-orbit communication test of the Mercury tracking network – the spacecraft was to shut down after the first three orbits, but could have been reactivated for as many as three more similar tests, if necessary; check out of the real-time Mercury computation facility at Goddard Space Flight Center and the communication link between Goddard and the Mercury range stations.

Spacecraft Payload – C- and S-band radar beacons, two telemetry transmitters, two command receivers, and two Minitrack beacons.

Test Results – Mercury-Scout I was launched from Cape Canaveral on November 1, 1961. The first stage of the Scout vehicle exploded 26 seconds after liftoff; the other three stages were destroyed by the range safety officer 44 seconds after launch.

RANGER II

Launch Vehicle – The Atlas-Agena B, with a modified Atlas D (360,000-pound-thrust) as the first stage and the Agena B (15,000-pound-thrust) serving as the second stage. Liftoff weight, approximately 275,000 pounds; total height, 102 feet; base diameter, 10 feet.

Spacecraft Description – The spacecraft was almost identical to Ranger I: a cone formed by aluminum struts and braces atop a hexagonal base, with two large solar panels extending from the base. Ranger II weighed 675 pounds; in orbital condition, with the solar panels and high-gain antenna in place, it was 13 feet high and 17 feet across the panels. A combination of gold plating, white paint, and polished aluminum surfaces comprised the spacecraft's passive temperature control system.

Project Objectives – Flight test various spacecraft systems designed for future lunar and interplanetary missions; investigate cosmic rays, magnetic fields, radiation, dust particles, and the possibility the earth is trailed by a comet-like tail of hydrogen gas.

Spacecraft Payload – Ranger II's experiment instrumentation included: 1) six charged-particle analyzers, 2) six medium-energy-range particle detectors, 3) quartz-fiber cosmic ray ionization chamber, 4) two triple-coincidence cosmic ray telescopes, 5) rubidium vapor magnetometer, 6) two solar X-ray scintillation counters, 7) telescope and Lyman-Alpha detector, 8) cosmic dust detectors, 9) four calibrated solar cells, 10) engineering friction experiment with 80 different combinations of metals. The spacecraft systems included a solid-state timer, sun and earth sensors, gyroscopes, pitch and roll jets, omni-directional antenna mounted on top, high-gain directional antenna positioned beneath the spacecraft, one 0.25-watt transmitter and one 3-watt transmitter on approximately 960 megacycles, 8680 solar cells and a 118-pound silver-zinc battery.

Test Results – Ranger II was carried into parking orbit by the second-stage Agena following a successful launch from Cape Canaveral on November 18, 1961. An inoperative Agena roll gyro permitted the second stage and spacecraft to spin through space, preventing Agena re-start to provide Ranger II sufficient escape velocity for its planned deep space trajectory. As with Ranger I, the spacecraft was injected into only a low earth orbit, and re-entered later the same day.

Major Participants – NASA Jet Propulsion Laboratory, California Institute of Technology, spacecraft design, integration, and tracking; USAF Systems Command, launch management; General Dynamics/Astronautics, Atlas prime contractor; Rocketdyne, Atlas propulsion; General Electric Company and Burroughs Corporation, Atlas guidance system; Lockheed Missiles and Space Company, Agena prime contractor; Bell Aerospace Company, Agena propulsion; Space Technology Laboratories, Inc., Atlas and Agena guidance equations.

Key Spacecraft Personnel		Affiliation
PM	James D. Burke	JPL
PS	Marcia M. Neugebauer	JPL
MG	Benjamin Milwitzky	JPL

Experiment	Experiment Personnel		Affiliation
Lyman Alpha Telescope	PI	R.W. Kreplin	US Naval Research Laboratory
Rubidium Vapor Magnetometer	PI	J.P. Heppner	NASA-GSFC
Electrostatic Analyzer	PI	M.M. Neugebauer	NASA-JPL
Med. Energy Particle Detectors	PI	J.A. Van Allen	University of Iowa
Triple Coincidence Telescope	PI	J.A. Simpson	University of Chicago
Cosmic Ray Ion Chamber	PI	V.H. Neher	California Institute of Technology
Cosmic Dust Detectors	PI	Unknown	Unknown
Scintillator Counters	PI	T.G. Northrop	NASA-GSFC

MERCURY-ATLAS V

Launch Vehicle – A modified Atlas D with 360,000-pound-thrust. Liftoff weight, approximately 260,000 pounds; height including capsule and escape system, 93 feet; base diameter, 10 feet.

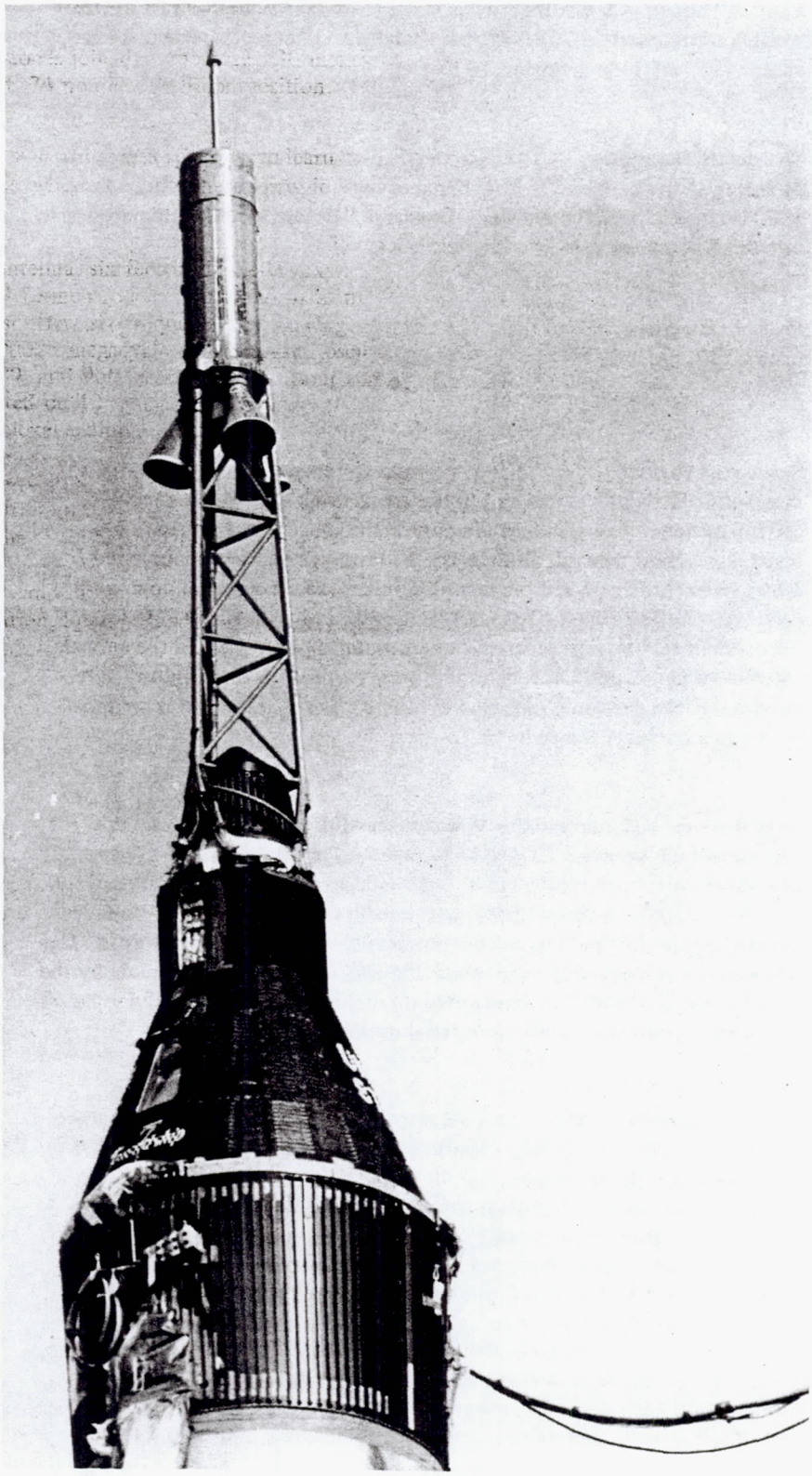
Spacecraft Description – The Mercury bell-shaped capsule was 6 feet in diameter at the base and 9 feet, 6 inches high; it weighed approximately 2900 pounds in orbital condition. One large "picture window" replaced the two small portholes used in earlier capsules.

Project Objectives – Final flight test of all Mercury systems prior to manned orbital flight; test the reaction of a chimpanzee under prolonged weightlessness.

Spacecraft Payload – Enos, a four-year-old chimpanzee, was fitted into a metal-and-plastic box connected to the spacecraft's normal environmental control system. The standard Mercury communication, stabilization and control, reaction control, and electrical power systems were employed. Two tape recorders played pre-recorded voice transmissions for communication system evaluation. Telemetry and recording equipment monitored major flight events; four separate camera systems photographed the animal, instrument panel, periscope view, and the view through the window. Four emulsion packs measured radiation exposure. The spacecraft was equipped with a quick-release escape hatch.

Test Results – Mercury-Atlas V was successfully launched from Cape Canaveral on November 29, 1961. Scheduled for three orbits, the spacecraft was returned after two orbits due to the failure of a roll reaction jet and the malfunction of an inverter in the environmental control system – both conditions apparently could have been corrected by an on-board astronaut. The spacecraft was successfully recovered 255 miles southeast of Bermuda by the USS Stormes. The chimpanzee suffered no ill effects and successfully passed various psychomotor tests administered during the flight.

Major Participants – NASA Manned Spacecraft Center, project management; McDonnell Aircraft Company, capsule prime contractor; Minneapolis-Honeywell Regulator Company, capsule stabilization and control system; Collins Radio Company, capsule instrumentation and communication systems; Garrett Corporation, capsule environmental control system; Northrop Ventura, capsule recovery system; Lockheed Propulsion Company, capsule escape rocket; USAF Systems Command, Atlas executive and launch management; General Dynamics/Astronautics, Atlas prime contractor; Aerospace Corporation, Atlas systems engineering and technical direction; Rocketdyne, Atlas propulsion; General Electric Company and Burroughs Corporation, Atlas guidance system; Space Technology Laboratories, Inc., Atlas guidance equations; Western Electric Company, tracking network prime contractor; US Navy, recovery task force management.

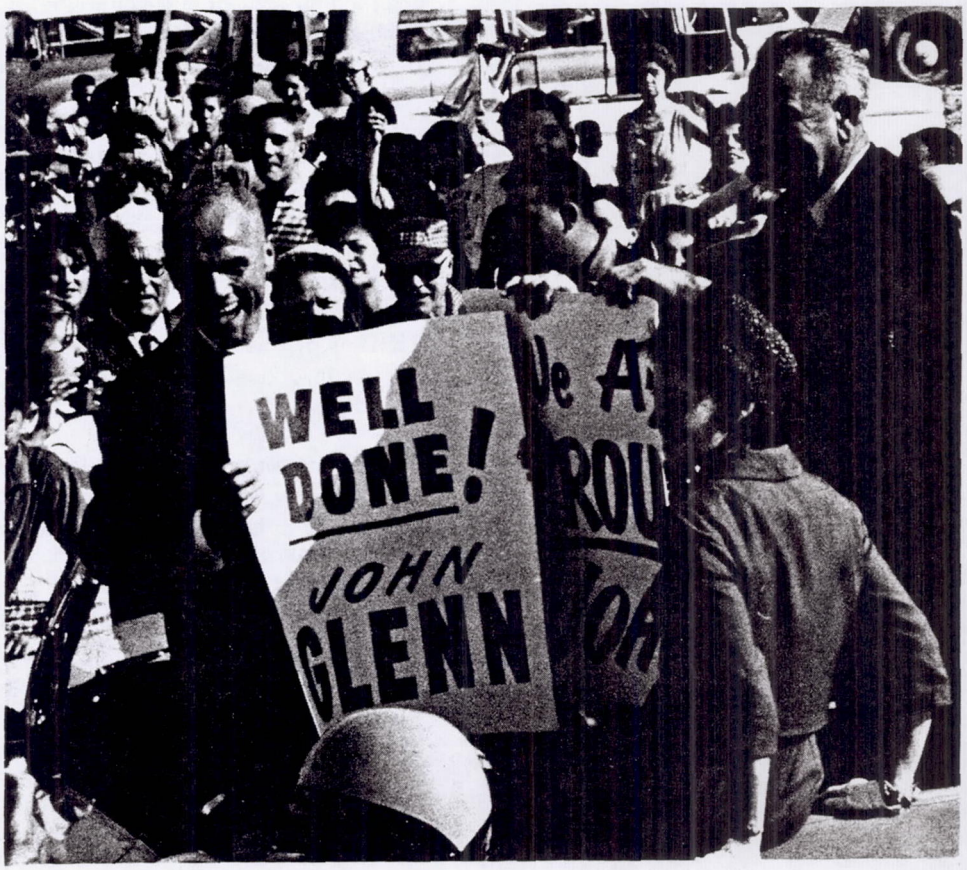


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(Left page) Atlas Booster with Friendship 7 capsule. In this capsule astronaut John H. Glenn, Jr. orbited the Earth three times in the first manned orbital flight by the United States. On February 20, 1962 Friendship 7 was launched on a flight which lasted 4 hours and 55 minutes. Later, Glenn was welcomed as a national hero by President Lyndon B. Johnson (top and right).



RANGER III

Launch Vehicle – Atlas-Agena B, same as Ranger II.

Spacecraft Description – The spacecraft was somewhat shorter and heavier than Ranger I and II due to a new mission and a new set of experiments. The spacecraft weighed 727 pounds, measured 17 feet across the wing-like solar panels, and was 10¼ feet high in orbital condition. A 25-inch balsa wood lunar capsule and retrorocket mounted on top of the spacecraft differentiated Ranger III from its predecessors. A silvered plastic sheet encased the retrorocket to provide thermal control.

Project Objectives – Impact the spacecraft and rough land an instrumental capsule on the moon, obtain television pictures of the lunar surface, study gamma radiation and radar reflectivity of the lunar surface; continuing engineering development of lunar and interplanetary spacecraft.

Spacecraft Payload – Inside the balsa wood capsule, designed to land on the moon at 80 to 100 mph, were a highly sensitive seismometer, amplifier, six silver/cadmium batteries, 50-milliwatt transmitter, temperature-sensitive voltage control oscillator, and a turnstile antenna. A radar altimeter on board the spacecraft was designed to initiate capsule separation and ignite the 5080-pound-thrust retrorocket, and to conduct reflectivity studies as the spacecraft approached the moon. Three television cameras and a telescope were carried to provide lunar photographs from an altitude of 2400 miles down to 15 miles. A gamma ray spectrometer was mounted on a six-foot boom. Spacecraft systems included a solid-state computer and sequencer, monopropellant mid-course motor, sun and earth sensors, gyroscopes, pitch and roll jets, omnidirectional antenna, high-gain antenna, 3-watt transmitter, 8680 solar cells and a 25-pound silver-zinc battery.

Test Results – Ranger III was launched from Cape Canaveral on January 26, 1962, and passed into solar orbit after missing the moon by 28,862 miles. Three malfunctions were encountered: the Atlas booster imparted excessive velocity to the Agena/Ranger III, a reversed mid-course signal caused the spacecraft to pitch the wrong direction, and a spurious signal during the terminal maneuver prevented the high-gain antenna from transmitting useful television pictures to the Goldstone tracking station. Scant scientific data was obtained; however, the flight was termed a partial engineering success.

Major Participants – NASA Jet Propulsion Laboratory, California Institute of Technology, spacecraft design, integration, and tracking; Aeronutronic, lunar capsule; USAF Systems Command, launch management; General Dynamics/Astronautics, Atlas prime contractor; Rocketdyne, Atlas propulsion; General Electric Company and Burroughs Corporation, Atlas guidance system; Lockheed Missiles and Space Company, Agena prime contractor; Bell Aerospace Company, Agena propulsion; Space Technology Laboratories, Inc., Atlas and Agena guidance equations.

Key Spacecraft Personnel		Affiliation
PM	James D. Burke	JPL
PS	Harold W. Washburn	JPL
MG	N. William Cunningham	

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	G.P. Kuiper	University of Arizona
Gamma Ray Detector	PI	J.R. Arnold	University of California, San Diego
	OI	E.C. Anderson	Los Alamos Scientific Laboratories
	OI	M.A. Van Dilla	Los Alamos Scientific Laboratories
	OI	A.E. Metzger	NASA-JPL
Radar Altimeter	PI	W.E. Brown	NASA-JPL
Seismometer	PI	F. Press	Massachusetts Institute of Technology
	OI	M. Weing	Columbia University

TIROS IV

Launch Vehicle – The three-stage Delta, similar to OSO I.

Spacecraft Description – Same as Tiros III – a cylinder 42 inches in diameter, 19 inches high; top and sides covered with 9260 solar cells; weight, 285 pounds.

Project Objectives – Continued research and development of a meteorological satellite system; obtain data for operational use in weather forecasting.

Spacecraft Payload – A new lens system for one of the two wide-angle vidicon cameras was the only major change from Tiros III; the new lens was designed to reduce distortion and provide better picture resolution. Photographic coverage for the new lens was 450 miles on a side and 750 miles for the other one-half inch, f1.5 lens. Each camera was equipped with a magnetic tape recorder to store up to 32 photographs and an electronic clock control the timing of various operations – programmed from ground sta at Wallops Island, Virginia, and San Nicholas Island, California. Other i strumentation included three infrared radiation experiments, one scan and two non-scanning; nine solar-cell direction indicators for picture tation; infrared horizon sensor; magnetic orientation control system mechanism and five pairs of small spin-up rockets; four transmi antennas and one receiving antenna; two 2-watt transmitters on 2 cycles for picture transmission, one 2-watt transmitter on 237.8 r cycle for infrared experiment data, two 30-milliwatt tracking beacons and 136.92 megacycles; 63 nickel-cadmium storage batteries ch solar cells.

Test Results – The fourth successful Tiros spacecraft was la Cape Canaveral on February 8, 1962; data from Tiros IV w the best transmitted to date. The U.S. Weather Bureau in tional radio facsimile transmission of cloud maps based o

Major Participants – NASA Goddard Space Flight Ce ment; Radio Corporation of America, Tiros prime co Bureau, data analysis; Barnes Engineering Company consin, radiation detectors; Douglas Aircraft Comp tractor; Rocketdyne, first stage propulsion; Aero second stage propulsion; Allegany Ballistics Lab sion; Bell Telephone Laboratories, Delta guidar

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Key Spacecraft Personnel		Affiliation
PM	R.M. Rados	NASA-GSFC
PS	Aerospace and Meteorology Division	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Omni Radiometer	PI	V.E. Suomi	University of Wisconsin
Widefield Radiometer	PI	R.A. Hanel	NASA-GSFC
Scanning Radiometer	PI	J.D. Barksdale	NASA-GSFC
Cloud Cover Television	PI	Ness Staff	NOAA-NESS
	CO	R.M. Rados	NASA-GSFC

FRIENDSHIP 7
(Mercury-Atlas 6)

Launch Vehicle – A modified liquid-propellant Atlas D (360,000-pound-thrust) was employed. Modifications included heavier skin at the forward end of the liquid oxygen tank, alterations to the payload adapter section to accommodate the spacecraft, and inclusion of an abort-sensing system. Liftoff weight, 260,000 pounds; total height including capsule and escape system, 93 feet; base diameter, 10 feet.

Spacecraft Description – The "Friendship 7" capsule weighed 2987 pounds in orbital condition and was 6 feet in diameter at the base and 9 feet, 6 inches high. The cylindrical neck at the top of the capsule contained the main and reserve parachute systems. A 0.01-inch titanium skin covered the conical body and an ablative fiberglass heat shield and retrorocket package were attached to the base of the spacecraft.

Project Objectives – Orbit and recover manned spacecraft; evaluate man-spacecraft performance; investigate man's capabilities in space environment; obtain astronaut's evaluation of operational suitability of spacecraft and supporting systems.

Spacecraft Payload – Astronaut John H. Glenn, Jr. and these major spacecraft systems: automatic stabilization and control system with three backu systems; two 16mm cameras to photograph the instrument panel and the astronaut, HF/UHF communication system, UHF telemetry system, eart periscope, 100-percent oxygen environmental control system, four-bat power supply with backup system, tubes of beef and vegetables a pounds of water, quick-release hatch, four-foot rubberized fiberglas skirt.

Test Results – Mercury-Atlas 6 was launched from Cape Canav planned near-earth orbit on February 20, 1962. Two major p encountered during the flight: a yaw attitude control jet ap requiring the astronaut to abandon the automatic control s manual-electrical "fly-by-wire" system and the manual-a faulty microswitch in the heat shield circuit indicated the shield in place had been prematurely released – th false but the retrorocket package was retained throug shield in place. The capsule re-entered and splashed 800 miles southeast of Bermuda after three orbits one-half hours of weightlessness. The capsule w after 21 minutes in the water; Astronaut Glenn condition. In his debriefing, Glenn reported v experience and stressed man's reliability and system. From a scientific standpoint, he o ticles surrounding the spacecraft for appr ...ate sunrise, and also noted an extremely bri band a

Major Participants – Same as Mercur

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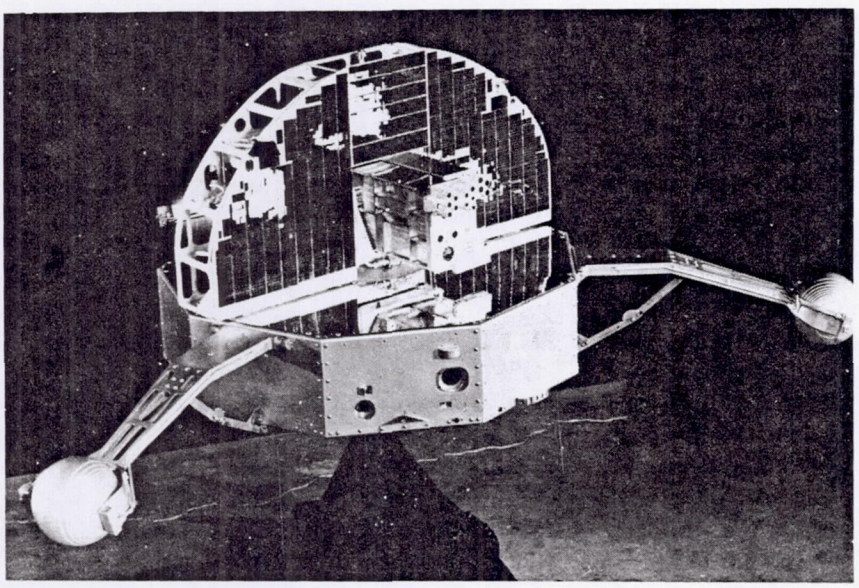
OSO I

Launch Vehicle – The three-stage Delta, with the first stage a modified Thor (150,000-pound-thrust), a liquid-propellant rocket adapted from Vanguard as the second stage (7500-pound-thrust), and a spin-stabilized solid rocket also modified from the Vanguard vehicle as the third stage (3000-pound-thrust). Liftoff weight, about 112,000 pounds; total height, 90 feet; base diameter, 8 feet.

Spacecraft Description – OSO I, a 458-pound, 37-inch high spacecraft was comprised of two sections: a nine-sided spinning base with a stabilized fan-shaped section riding on top. The spinning section was 44 inches in diameter and contained nine wedge-shaped compartments, five for experiments and four for various spacecraft systems. Three fiberglass balls extended on arms from the base to give it an overall diameter of 92 inches. The balls contained pressurized nitrogen for the gyroscopic control system, maintaining a spin rate of 30 rpm.

Project Objectives – Measure electromagnetic radiation from the sun in the ultraviolet, X-ray, and gamma ray regions of the spectrum and study time variations of the emissions.

Spacecraft Payload – The spacecraft's upper section was designed to point experiments at the sun with an accuracy of one minute of arc in elevation and azimuth. Coarse elevation control of the stabilized section was accomplished by jets mounted on the section; azimuth and fine elevation positioning of the instruments was provided by electrical servo motors. The pointing experiments included three solar X-ray experiments, a gamma ray experiment, and a microscopic dust particle experiment. The lower section



OSO-1 observed close to 75 solar flares. It enabled scientists to gather new knowledge about the sun-earth relationships and to learn more about the Earth's "mother star"

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included instrumentation to study solar radiation, solar ultraviolet, solar gamma rays, the lower Van Allen radiation belt, spacecraft thermal control, and a neutron monitoring experiment. Systems located in the lower section included a tape recorder, telemetry, and two independent and parallel transmitters. Two of the extended arms served as the spacecraft's antenna, and 1860 solar cells mounted on the stabilized section and nickel-cadmium batteries provided the spacecraft's supply.

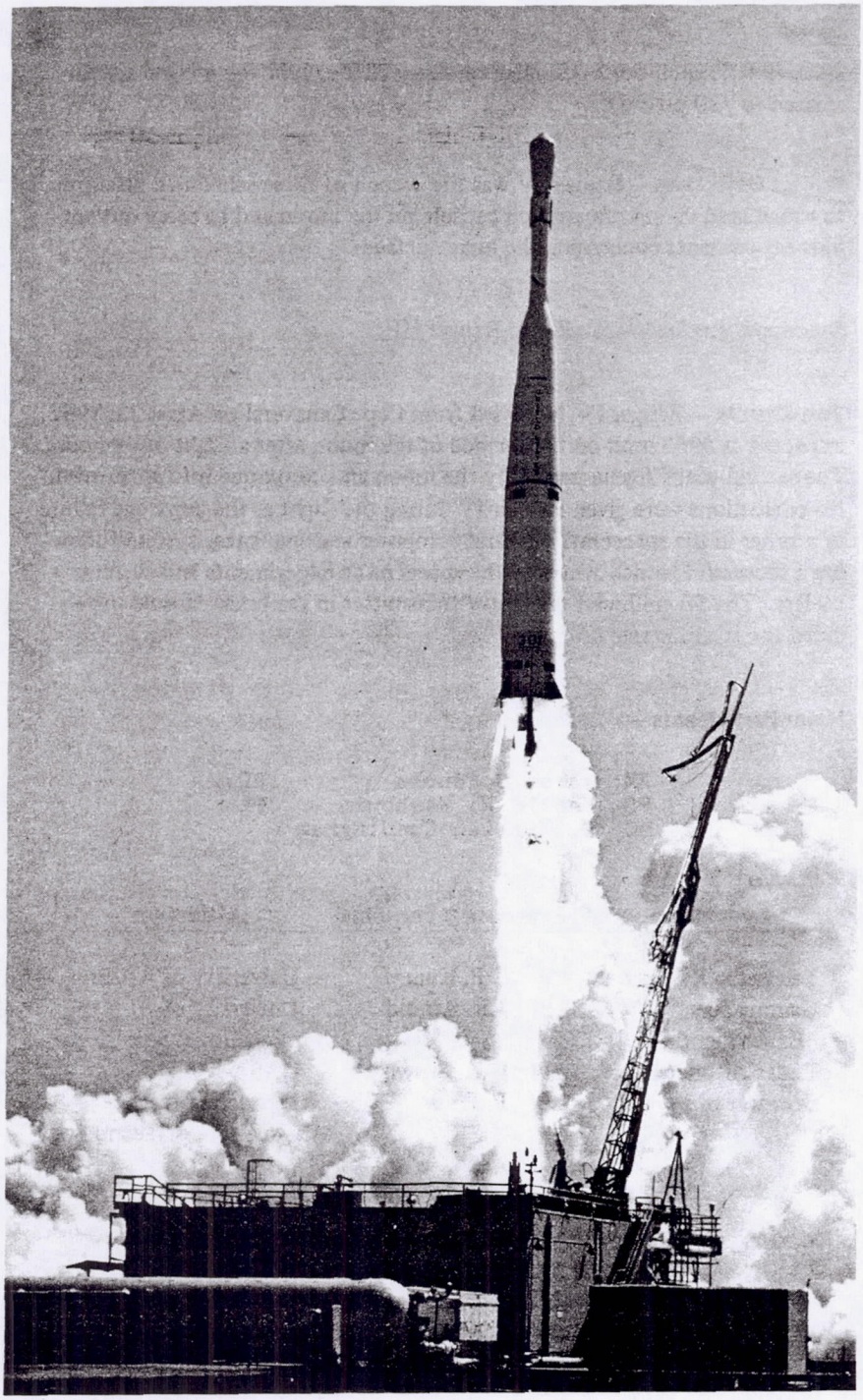
Test Results – OSO I was successfully launched from Cape Canaveral into a near-circular orbit on March 7, 1962. The spacecraft ceased transmitting useful information on May 22 due to a malfunction in the spin control system. OSO I's thirteen experiments transmitted almost 1000 hours of useful information on solar phenomena, including measurements on 75 solar flares and subflares.

Major Participants – NASA Goddard Space Flight Center, project management, OSO experiments; Ball Brothers Research Corporation, OSO prime contractor; NASA Ames Research Center, Universities of California, Minnesota, and Rochester, OSO experiments; Douglas Aircraft Company, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General Corporation, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.

Key Spacecraft Personnel		Affiliation
PM	J.C. Lindsay	NASA-GSFC
SC	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
10-400A UV Spectrometer	PI	W.M. Neupert	NASA-GSFC
	OI	W.E. Behring	NASA-GSFC
20-100keV Scintillation Detector	PI	K.J. Frost	NASA-GSFC
Gamma Ray Monitor	PI	K.J. Frost	NASA-GSFC
1-8A Ion Chamber	PI	W.A. White	NASA-GSFC
Dust Particles	PI	C.W. McCracken	NASA-GSFC
Solar Flux Monitor	PI	K.L. Hallam	NASA-GSFC
Solar Lyman Alpha Ion Chamber	PI	K.L. Hallam	NASA-GSFC
50 keV 3-MeV Gamma Ray Experiment	PI	L.E. Peterson	University of California, San Diego
High Energy Gamma Ray Experiment	PI	G.G. Fazio	SAO
BF3 Prop Center Neutron Detector	PI	W.N. Hess	NOAA-ERL
Inner Van Allen Belt Experiment	PI	C.D. Schrader	Lawrence Livermore Laboratories
	OI	J.A. Waggoner	
Emissivity Experiment	PI	C.B. Neel, Jr.	NASA-ARC

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OSO-1, the first orbiting solar observatory, leaves the launch pad on a Delta 8.

Note: NASA's Orbiting Solar Observatory (OSO) program investigated a broad spectral range of solar radiation. Experiments previously hindered on earth by the absorbing effects and distortions of the atmosphere were conducted from stabilized, sun-oriented space platforms designed to point scientific instruments with extreme accuracy.

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RANGER IV

Launch Vehicle – The Atlas-Agena B, same as Ranger II.

Spacecraft Description – Similar to Ranger III except the weight was increased to 730 pounds.

Project Objectives – Ranger IV was the second of three scheduled attempts to rough land an instrumentated capsule on the moon and to carry out various experiments concerning the lunar surface.

Spacecraft Payload – Similar to Ranger III.

Test Results – Ranger IV, launched from Cape Canaveral on April 23, 1962, impacted at 5963 mph on the far side of the moon after a flight of 64 hours. The second-stage Agena passed by the moon and continued into solar orbit. No corrections were given Ranger IV during the flight as the apparent failure of a timer in the spacecraft's central computer and sequencer system following a successful launch rendered the spacecraft's experiments and systems useless. The 50-milliwatt telemetry transmitter in the lunar capsule provided the tracking signal for the flight.

Major Participants –

PM	James D. Burke	JPL
PS	Harold W. Washburn	JPL
MG	N. William Cunningham	

Experiment	Experiment Personnel	Affiliation
Television Experiment	PI G.P. Kuiper	Univeristy of Arizona
Gamma Ray Experiment	PI J.R. Arnold	University of California, San Diego
Radar Altimeter	PI W.E. Brown	NASA-JPL
Seismometer	PI F. Press	Massachusetts Institute of Technology

ARIEL I

Launch Vehicle – The three-stage Delta, similar to OSO I.

Spacecraft Description — The 132-pound Ariel (named for the airy spirit of Shakespeare's The Tempest) was basically a short, fat cylinder rounded on both ends, 23 inches in diameter and 20 1/2 inches high. Four solar paddles and two 4-foot experiment booms extended from the lower spherical section. A spherical experiment package was mounted on a short column atop the spacecraft. The epoxy-bonded fiberglass shell was gold plated and painted black and white for thermal control.

Project Objectives – The spacecraft carried six British experiments to study the ionosphere, solar radiation, and cosmic rays.

Spacecraft Payload – Experiment instrumentation: Cerenkov cosmic ray detector, ion mass sphere electron density sensor, two electron temperature gauges, three Lyman-Alpha detectors, two proportional X-ray counters. Spacecraft systems included a steel spring de-spin mechanism, PFM telemetry system, command receiver, transmitter on 136.410 megacycles, modified turnstile antenna array, tape recorder, and a solar cell and nickel-cadmium power supply.

Test Results – Ariel was successfully launched from Cape Canaveral on April 27, 1962, into an elliptical orbit.

Major Participants – NASA Goddard Space Flight Center, project and spacecraft management; British National Committee on Space Research, spacecraft experimental management; University College, University of Birmingham, Imperial College, University of Leicester, spacecraft experiments; Douglas Aircraft Company, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General Corporation, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.

Key Spacecraft Personnel		Affiliation
PM	M.O. Robbins	Science Research Council
PM	R.C. Baumann	NASA-GSFC
PS	R.L.F. Boyd	Mullard Space Science Laboratory
PS	K.A. Pounds	University of Leicester
PS	J. Sayers	University of Birmingham
PS	H. Elliot	Imperial College

Key Spacecraft Personnel		Affiliation
PS	R.E. Bourdeau	NASA-GSFC
PE	J.T. Shay	NASA-GSFC
SC	H. Massey	University College London
PC	E.B. Dorling	University College London
PI	K. Bullough	University of Sheffield

Experiment	Experiment Personnel		Affiliation
Langmuir Probe	PI	J. Sayers	University of Birmingham
	OI	P.H.M. Rothwell	University of Southampton
	OI	J.H. Wager	University of Birmingham
Electron Temperature	PI	R.L.P. Boyd	University College London
	OI	A.P. Willmore	University of Birmingham
Cosmic Ray Detector	PI	H. Elliott	Imperial College
	OI	J.J. Quenby	Imperial College
	OI	R.J. Hynds	Imperial College
	OI	A.C. Durney	ESA-ESTEC
	CO	D.W. Mayne	Appleton Laboratories
Ion Composition	PI	R.L.F. Boyd	University College London
Lyman Alpha Gauge	PI	J.A. Bowles	University College London
Extra-Terrestrial Soft X-Ray	PI	R.L.F. Boyd	University College London

AURORA 7
(Mercury-Atlas 7)

Launch Vehicle – A modified 360,000-pound-thrust Atlas D was employed. Alterations to the 1½ stage vehicle included heavier skin at the forward end of the liquid oxygen tank, modification of the payload adapter section and inclusion of an abort sensing and implementation system. Liftoff weight, 260,000 pounds; total height including capsule and 16-foot escape tower, 93 feet; base diameter, 10 feet.

Spacecraft Description – The bell-shaped "Aurora 7" capsule weighed 2975 pounds at insertion into orbit and was 6 feet in diameter at the base and 9 feet, 6 inches high. Titanium skin covered the conical body and an ablative fiberglass heat shield and retrorocket package were attached to the base of the spacecraft.

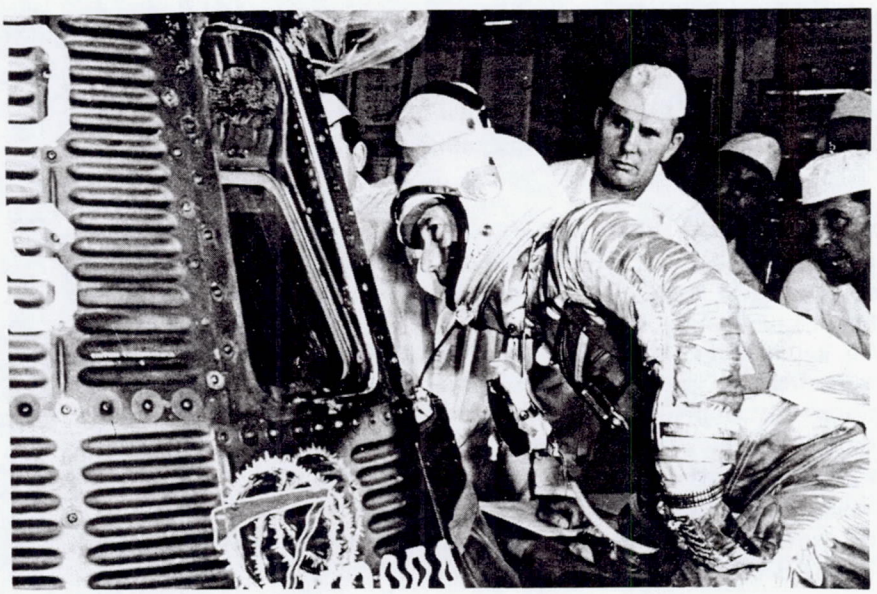
Project Objectives – Orbit and recover manned spacecraft; evaluate man-spacecraft performance; investigate man's capabilities in space environment; obtain astronaut's evaluation of operational suitability of spacecraft and supporting systems. The flight was scheduled to go three orbits.

Spacecraft Payload – Astronaut M. Scott Carpenter, automatic stabilization and control system with three backup systems – rate command, manual-mechanical and manual-electrical (fly-by-wire), 100 percent oxygen environmental control system, HF/UHF communication system and UHF telemetry system, UHF/DF recovery beacon, four-battery power supply with backup system, 16mm camera to photograph the astronaut, earth periscope, pilot support couch and restraint system, pressure suit, aeromedical monitor system, 3000 calories of non-residue food and six pounds of water, survival equipment and life raft, four-foot rubberized fiberglass impact skirt, drogue, main and reserve parachutes. Two capsule modifications were made based on difficulties encountered during John Glenn's M-A 7 flight: switches actuating heat shield deployment were rewired and the low-thrust attitude control chambers were redesigned to prevent clogging. Several scientific experiments were also carried including an inflatable balloon to measure drag and provide visibility data, a glass sphere containing a capillary tube to examine the behavior of a liquid in weightless state and a hand-held 35mm camera for various photographic experiments.

Test Results – Aurora-7 (Mercury-Atlas 7) was launched from Cape Canaveral on May 24, 1962, into near-earth orbit. All primary mission objectives were achieved. The capsule re-entered under manual control after three orbits and four hours, 56 minutes, and landed 125 miles northeast of Puerto Rico, 250 miles beyond the planned impact point. Search aircraft had positive UHF/DF contact with the spacecraft 18 minutes after landing and visual contact after 40 minutes – they found the astronaut seated comfortably in his life raft beside the floating spacecraft. Shortly thereafter a SC-54 aircraft deployed a pararescue team with survival equipment and an auxiliary spacecraft flotation collar. Carpenter was picked up by helicopter after two hours, 59 minutes in the water and was taken to the USS Intrepid for initial debriefing and medical examination. Neither physical nor bio-

chemical detrimental effects were found as the flight appeared to be no more demanding than an aircraft test flight. A failure in the spacecraft pitch horizon scanner was the only critical malfunction during the flight. Cabin and pressure suit temperatures were high but not intolerable. Excessive fuel usage, resulting from extensive use of high thrust controls and inadvertent use of two control systems simultaneously, was a major concern during the flight. The spacecraft was allowed to drift free for a total of 77 minutes to conserve fuel and to evaluate the behavior of the astronaut and vehicle. The 250 mile overshoot on re-entry was traced primarily to an average yaw error of 27 degrees during retrofire. Retrofire was 3-4 seconds late, contributing 15-20 miles of the miss distance. The zero-gravity experiment verified the predicted behavior of the liquid in a weightless stage but the balloon experiment was only partially successful as the sphere failed to fully inflate. Visual and photographic investigations of the luminous band around the horizon attributed to airglow, the particles noticed by John Glenn at sunrise (believed to be ice crystals from the spacecraft) and the flattened solar image at sunset were all successfully carried out.

Major Participants – NASA Manned Spacecraft Center, project management; Goddard Space Flight Center, tracking and data acquisition; McDonnell Aircraft Company, capsule prime contractor; Minneapolis-Honeywell Regulator Company, stabilization and control system; Collins Radio Company, instrumentation and communication systems; Garrett Corporation, environmental control system; Northrop Ventura, recovery system; Lockheed Propulsion Company, escape rocket; USAF Systems Command, launch vehicle management; General Dynamics/Astronautics, Atlas prime contractor; Aerospace Corporation, Atlas systems engineering; Rocketdyne, Atlas propulsion; General Electric Company and Burroughs Corporation, Atlas guidance system; Space Technology Laboratories, Inc., Atlas guidance equations; Western Electric Company, tracking network prime contractor, US Navy, recovery task force management.



Astronaut M. Scott Carpenter inspects Aurora 7 spacecraft prior to launch on May 24, 1962.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

TIROS V

Launch Vehicle – Delta, with a Thor DM-19 (150,000-pound-thrust) first stage, 7500-pound-thrust second stage and spin stabilized solid propellant third stage (3000-pound-thrust). Liftoff weight, about 112,000 pounds; total height, 90 feet; base diameter, 8 feet.

Spacecraft Description – A cylinder 42 inches in diameter and 22 inches high; top and sides covered with solar cells; weight, 285 pounds.

Project Objectives – Continue development of a meteorological satellite system; maintain an operational Tiros vehicle in orbit (Tiros IV ceased useful operation on June 10, 1962); provide hurricane observation capability during mid-August and September; increase area coverage.

Spacecraft Payload – The two camera systems utilized one-half inch vidicon tubes, one with a wide-angle Elgeet lens designed to photograph an area 900 miles on a side from an altitude of 400 miles, and the other employing a medium-angle Tegea lens designed to cover an area 550 miles on a side. Each camera system also included a tape recorder, electronic clock and two-watt transmitter operating on 235 megacycles. Spacecraft systems included an infrared horizon scanner, north indicator, despin weights and spinup rockets, magnetic attitude control coil, 9260 solar cells and 63 nickel-cadmium batteries, two tracking beacons, four telemetry antennas extending from the baseplate and a receiving antenna located on top of the spacecraft. Three infrared experiments carried on board were disconnected prior to launch when they failed to pass pre-flight checkout.

Test Results – Tiros V was successfully launched from Cape Canaveral on June 19, 1962. Its inclination was 58.3 degrees, ten degrees higher than previous Tiros spacecraft to extend observations to the higher latitudes. Orbit was elliptical, ranging from 367 to 604 miles, instead of the programmed 400-mile circular orbit, due to a malfunction in the Delta's ground guidance equipment. Excellent pictures were received at the end of the first orbit and a storm over Canada was photographed on the third orbit. The medium-angle camera failed on July 6 after transmitting 4701 pictures. Tiros V observed ice breakup in northern latitudes as well as storms originating in these areas, and provided the initial warning on half of the world's ten most serious storms during August.

Major Participants – NASA Goddard Space Flight Center, project management; Radio Corporation of America, Tiros prime contractor; U.S. Weather Bureau, data analysis and distribution; Douglas Aircraft Company, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General Corporation, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.

Key Spacecraft Personnel		Affiliation
PM	R.M. Rados	NASA-GSFC
PS	Aerospace and Meteorology Division	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	Ness Staff	NOAA-NESS
	CO	R.M. Rados	NASA-GSFC

TELSTAR I

Launch Vehicle – Three-stage Delta with a modified Thor DM-19 (150,000-pound-thrust) first stage, 7500-pound-thrust liquid propellant second stage and a spin stabilized solid propellant 3000-pound-thrust third stage. Lift-off weight, about 112,000 pounds; total height, 90 feet; base diameter, 8 feet.

Spacecraft Description – A 170-pound, 34.5-inch sphere with a magnesium structure and aluminum skin covered with solar cell patches. A helical antenna extended from the top of the spacecraft.

Project Objectives – Primary purpose was to conduct communication experiments between the BTL satellite and the company's Andover, Maine, ground station, as well as other U.S. and foreign stations. The flight was also designed as an engineering test of the world's first commercial satellite. In addition, the spacecraft carried an experiment package to obtain data on space environment.

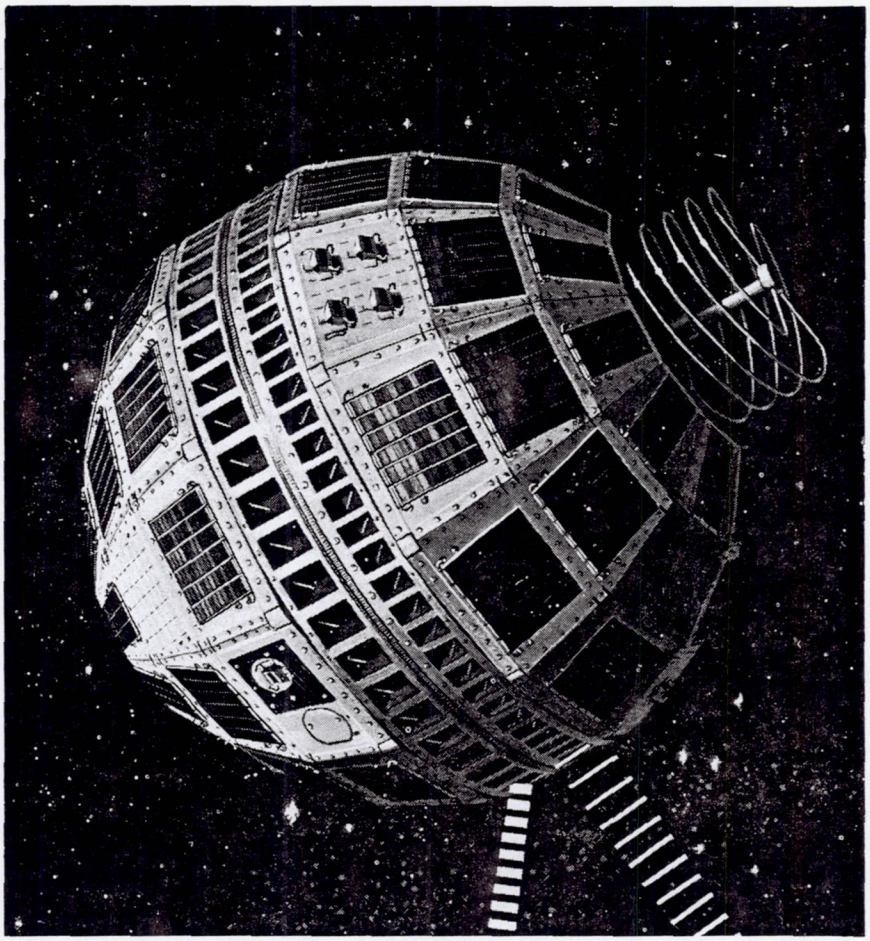
Spacecraft Payload – Telstar I's broadband active repeater communication system was designed to receive on 6390 megacycles, retransmit on 4170 megacycles with an output of 2¼ watts through a traveling wave tube. The system was capable of providing 600 one-way voice channels or one television channel. PCM-FM-AM telemetry was transmitted on 136 megacycles; dual command receivers controlled the communication and telemetry systems. Two microwave equatorial antennas received and transmitted communication signals and the helical antenna handled telemetry, command and beacon signals. 3600 solar cells, shielded with man-made sapphire, provided an initial output of 15 watts to the 19-cell rechargeable nickel-cadmium battery. All electronic equipment was encapsulated in a 20-inch aluminum canister suspended within the satellite structure by nylon cord lacing. Three mirrors were mounted on the exterior of the spin stabilized spacecraft to provide orientation data. Four special silicon diodes were carried on board Telstar I to measure radiation intensity; a second experiment designed to measure radiation damage to semiconductors employed three solar cells and six silicon transistors.

Test Results – Telstar I was successfully launched from Cape Canaveral on July 10, 1962. On the sixth orbit the first telephone and television experiments were carried out. On the 15th orbit an eight minute television program from France was carried by U.S. networks. The spacecraft was within range of the Maine ground station up to 250 minutes each day, with mutual visibility between Maine and stations in England and France a maximum of 102 minutes per day. All communication transmissions originally planned– overseas telephony, black-and-white and color television facsimile, high and low speed data – were successfully carried out. Preliminary radiation exper-

iment results indicated the amount of protons to be about as predicted, but the number of energetic electrons was about ten times the amount expected. Degradation of the variably shielded solar cells and transistors followed the anticipated pattern.

Major Participants – Telstar I was the world's first commercial satellite, it was built by AT&T's Bell Telephone Laboratories; British General Post Office and French Center for Telecommunications Studies, European ground stations; National Aeronautics and Space Administration, launch management and tracking services; Douglas Aircraft Company, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General Corporation, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion.

Telstar 1, the first active repeater communications satellite, was built by private industry.



MARINER I

Launch Vehicle – Atlas-Agena B, with a modified Atlas D (360,000-pound-thrust) first stage and an Agena B (15,000-pound-thrust) second stage. Liftoff weight, 275,000 pounds; height, 100 feet; base diameter, 10 feet.

Spacecraft Description – Similar to the Ranger series design with a tubular superstructure mounted on a hexagonal base. Two solar panels extended from the base and a high-gain antenna was hinge-mounted below the base. Mariner I weighed 447 pounds and in launch configuration was 5 feet in diameter at the base and 9 feet, 11 inches high. In cruise position with solar panels and high-gain antenna extended, the spacecraft was 16.5 feet across the panels and almost 12 feet high.

Project Objectives – Inject the spacecraft into Venus flyby trajectory; make infrared and microwave measurements of the planet; make fields and particles measurements in interplanetary space and at the planet; communicate experiment data to earth over distances up to 36 million miles.

Spacecraft Payload – The spacecraft's attitude control system employed ten cold nitrogen gas jets linked with three gyros, an earth sensor and six sun sensors. A hydrazine-fueled midcourse correction motor (50-pound-thrust for up to 43 seconds) was carried to adjust trajectory to an optimum Venus miss distance of 10,000 miles. The communication system consisted of a receiver/transmitter and omnidirectional, high-gain and command antennas; transmitting power was 3 watts. A combination of insulating shields, louvers, paint patterns, aluminum sheet and gold plating was utilized in the thermal control system. 9800 solar cells designed to produce a minimum of 148 watts served as the primary power supply; initial and backup power was provided by a silver/zinc battery. A digital central command computer and sequencer performed all system computation and issued commands in three sequences – launch, midcourse and encounter. Mariner I carried two planetary experiments: 1) microwave radiometer to determine surface temperature and atmospheric details, 2) infrared radiometer to determine structure of the planet's cloud cover. Interplanetary experiments included: 1) fluxgate magnetometer to measure strength and direction of magnetic fields, 2) ion chamber and three Geiger-Mueller tubes to measure intensity and number of energetic particles, 3) cosmic dust detector to measure the flux and momentum of cosmic dust particles, 4) solar plasma detector to measure flow and density of solar plasma and the energy of its particles.

Test Results – Mariner I was launched from Cape Canaveral on July 22, 1962. The vehicle was destroyed by the range safety officer about 290 seconds after launch when it veered off course. The failure apparently was caused by a combination of two factors: improper operation of the Atlas airborne beacon equipment resulting in a loss of the rate signal from the vehicle for a prolonged period and incorrect data-editing equations. The airborne beacon transmitter used for obtaining rate data was inoperative for

four periods ranging from 1.5 to 61 seconds. During these periods the data-editing portion of the guidance equations incorrectly accepted the sweep frequency of the ground receiver as it sought the vehicle beacon signal and combined this data with the tracking data sent to the remaining guidance computation. The resulting erroneous steering commands led to the eventual destruction of the vehicle.

Major Participants - NASA Jet Propulsion Laboratory, California Institute of Technology, spacecraft design, integration and tracking; USAF Systems Command, launch management; General Dynamics/Astronautics, Atlas prime contractor; Rocketdyne, Atlas propulsion; General Electric Company and Burroughs Corporation, Atlas guidance system; Lockheed Missiles and Space Company, Agena prime contractor; Bell Aerospace Company, Agena propulsion; Space Technology Laboratories, Inc., Atlas and Agena guidance equations.

Key Spacecraft Personnel		Affiliation
PM	Jack N. James	JPL
PS	R. C. Wyckoff	JPL
MG	Fred Kochendorfer	

Experiment	Experiment Personnel		Affiliation
Micro Radiometer	PI	D.E. Jones	Brigham Young Univ.
	OI	A. E. Lilley	Harvard Univ.
	OI	A. H. Barrett	Massachusetts Institute of Tech.
Infrared Radiometer	PI	G. Neugebauer	California Institute of Tech.
3 Axis Fluxgate Magnetometer	PI	P. J. Coleman, Jr.	Univ. of Calif., La Jolla
Cosmic Ray Ionization	PI	H. R. Anderson	Rice University
	OI	J. A. Van Allen	Univ. of Iowa
	OI	V. H. Neher	Calif. Institute of Technology
Cosmic Dust Experiment	PI	W. M. Alexander	Baylor University
Electrostatic Analyzer	PI	M. M. Neugebauer	NASA-JPL
	OI	C. W. Snyder	NASA-JPL
Particle Detector	PI	J. A. Van Allen	Univ. of Iowa
Celestial Mechanics	CO	M. Sanders	NASA-JPL
	PI	J. D. Anderson	NASA-JPL

MARINER II

Launch Vehicle - Atlas-Agena B, same as Mariner I. Measures were taken to correct the difficulties experienced in the Mariner I launch, including a more rigorous checkout of the Atlas rate beacon and revision of the data-editing equations.

Spacecraft Description - Similar to Mariner I.

Project Objectives - Second of two U.S. Venus flyby missions scheduled for the 1962 launch window. Objectives were the same as for Mariner I.

Spacecraft Payload - Spacecraft systems and experiments were similar to Mariner I.

Test Results - Mariner II was launched into parking orbit from Cape Canaveral on August 27, 1962, then ejected from the Agena into a Venus flyby trajectory. The midcourse maneuver was successfully accomplished on September 4, reducing the Venus miss distance from 233,000 to about 20,900 miles. The spacecraft suffered a sudden voltage drop on October 30 and the four interplanetary experiments were turned off. Just as abruptly, the power level returned to normal nine days later and the experiments were turned on again. On November 25 Mariner II established a new long-distance communication record, breaking Pioneer 5's deep space record of 22.5 million miles set in June, 1960. Mariner II was to pass by the sunward side of Venus on December 14, 1960. The spacecraft's interplanetary experiments provided significant data on a continuous solar wind, reduced cosmic dust density, and particle and magnetic field variations with solar disturbances.

Major Participants - NASA Jet Propulsion Laboratory, California Institute of Technology, spacecraft design, integration and tracking; USAF Systems Command, launch management; General Dynamics/Astronautics, Atlas prime contractor; Rocketdyne, Atlas propulsion; General Electric Company and Burroughs Corportion, Atlas guidance system; Lockheed Missiles and Space Company, Agena prime contractor; Bell Aerospace Company, Agena propulsion; Space Technology Laboratories, Inc., Atlas and Agena guidance equations.

Key Spacecraft Personnel		Affiliation
PM	Jack N. James	JPL
PS	R. C. Wyckoff	JPL
MG	Fred Kochendorfer	

TIROS VI

Launch Vehicle – Three-stage Delta, same as Tiros V.

Spacecraft Description – Shaped like a drum – 42-inch diameter, 22 inches high; top and sides covered with solar cells; weight, 281 pounds.

Project Objectives – Provide maximum observation coverage during the last half of the 1962 hurricane season; furnish support for Mercury-Atlas 8 launch; continue development of an automated cloud pattern identification system.

Spacecraft Payload – Camera and spacecraft systems similar to Tiros V. Infrared experiments were not carried as the launch had originally been scheduled for November.

Test Results – The sixth consecutive Tiros was successfully launched on September 18, 1962, from Cape Canaveral. Tiros 6's initial orbit ranged from 425 to 442 miles with an inclination of 58.3 degrees. The spacecraft continues to return high quality cloud cover photographs.

Major Participants – Same as Tiros V.

Key Spacecraft Personnel		Affiliation
PM	R.M. Rados	NASA-GSFC
PS	Aerospace and Meteorology Division	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	Ness Staff	NOAA-NESS
	CO	R.M. Rados	NASA-GSFC

ALOUETTE I

Launch Vehicle – Thor-Agena B with a Thor DM-21 (170,000-pound-thrust) first stage and 16,000-pound-thrust Agena B second stage. Liftoff weight, 123,500 pounds; total height, about 90 feet; base diameter, 8 feet.

Spacecraft Description – Named for a high-flying Canadian lark, Alouette I was an oblate spheroid 42 inches in diameter and 34 inches high. A pair of crossed dipole antennas extended from the spacecraft's equator – one dipole measured 150 feet, the other 75 feet. The spun aluminum skin was covered with solar cells.

Project Objectives – Measure variations in ionosphere electron density distribution as a function of time of day and latitude as part of NASA's Topside Sounder program; measure galactic or radio noise that appears to originate in outer space and the radio noise within the ionosphere; observe primary cosmic ray particles.

Spacecraft Payload – Alouette's S-27 payload employed a swept frequency transmitter to probe the ionosphere from 1.6 to 11.5 megacycles. The unique sounding antennas were stored within the spacecraft at launch, then unreeled through guide sleeves to form long tubes. A FM telemetry system, with four whip antennas mounted in turnstile array, transmitted the time delay found at each frequency. Cosmic noise across a frequency range of 0.5 to 13 megacycles was also measured. In addition, Alouette carried a VLF receiver to listen for whistler signals and six particle detectors. The spin-stabilized spacecraft employed 6480 solar cells shielded with 12 mil glass plus 12 nickel-cadmium batteries.

Test Results – Alouette I was launched into a near-circular polar orbit from Vandenberg AFB on September 28, 1962. Canada thus became the third nation to completely design and build an earth satellite. Initial reports indicated the spacecraft was functioning properly and returning excellent experimental data to 13 Canadian, British and U.S. stations. An extensive ground-based sounding program was simultaneously initiated in an effort to compile a complete ionosphere profile of Canada and other regions of the world. Alouette's solar cell performance degraded 20 percent in the first 11 days in orbit.

Major Participants – Canadian Defence Research Telecommunications Establishment, project, spacecraft and experiment management; Canadian National Research Council, cosmic particle experiment; DeHaviland Aircraft Company, spacecraft structure and sounding antennas; National Aeronautics and Space Administration, launch management and tracking services; Douglas Aircraft Company, Thor prime contractor; Rocketdyne, Thor propulsion; Bell Telephone Laboratories, Thor guidance system; Lockheed Missiles and Space Company, Agena prime contractor; Bell Aerospace Company, Agena propulsion.

Note: Canada was the first nation to develop a complete satellite under NASA's international space research program.

Key Spacecraft Personnel		Affiliation
PE	C.A. Franklin	Communication Research Centre
PS	J.E. Jackson	NASA-GSFC
PS	E.S. Warren	Communication Research Centre
MG	F.W. Gaetang	NASA Headquarters
SC	J.H. Chapman	Comunication Research Centre
SC	E.R. Schmerling	NASA Headquarters
PM	J.E. Jackson	NASA-GSFC
CO	J.H. Whitteker	Communication Research Centre
PM	R.K. Brown	Communication Research Centre
MG	J.S. Johnson	Communication Research Centre

Experiment	Experiment Personnel		Affiliation
Sweep Frequency Sounder	PI	J.H. Whitteker	Communication Research Centre
	OI	J.E. Jackson	NASA-GSFC
	OI	L. Colin	NASA-ARC
	OI	J.W. King	Appleton Laboratories
	OI	R.W. Knecht	National Bureau of Standards
	OI	G.L. Nelms	Defence Research Establishment
Energetic Particle Detector	PI	I.B. McDiarmid	National Research Council of Canada
VLF Receiver	PI	J.S. Belrose	Communication Research Centre
	OI	F.H. Palmer	Communication Research Centre
	CO	F.H. Palmer	Communication Research Centre
Radio Astro, 1.5-10MHz	PI	T.R. Hartz	Communication Research Centre

EXPLORER XIV

Launch Vehicle – Three-stage Delta with the first stage a Thor DM-21 (170,000-pound-thrust), a liquid propellant 7500-pound-thrust second stage and solid propellant third stage (3000-pound-thrust). Liftoff weight, approximately 120,000 pounds; total height, about 90 feet; base diameter, 8 feet.

Spacecraft Description – Explorer XIV (S-3A) utilized the same design as Explorer 12: a truncated cone mounted beneath an octagonal platform. Four solar paddles, a 34-inch column supporting a magnetometer package and four telemetry antennas in turnstile array extended from the platform. Explorer XIV had an aluminum skin, was 27 inches across the flats of the octagon and 51 inches high, and weighed 89 pounds.

Project Objectives – A follow-on to Explorer XII, Explorer XIV was designed to monitor trapped corpuscular radiation, solar particles, cosmic radiation and the solar winds, and to correlate particle phenomena with magnetic field observations.

Spacecraft Payload – Experiment instrumentation included: 1) proton analyzer, 2) three-core fluxgate magnetometer, 3) one geiger omnidirectional particle detector and three directional detectors, 4) cosmic ray package with a double scintillation telescope, cadmium sulfide scintillation counter and two geiger counters, 5) ion-electron scintillation detector, 6) n-on-p and p-on-n, shielded and unshielded solar cells. Six solar sensors provided data on the spacecraft's orientation. The real-time PFM telemetry system employed a two-watt transmitter. Despin weights were carried to reduce the satellite's spin rate to 12 rpm. The 6144 solar cells shielded with 6 mil glass, charged 13 silver-cadmium batteries.

Test Results – Explorer XIV was launched from Cape Canaveral on October 2, 1962, into a highly elliptical orbit with an apogee of 61,000 miles and a perigee of 175 miles. Excellent preliminary data was received.

Major Participants – NASA Goddard Space Flight Center, project management, payload experiments; NASA Ames Research Center, University of New Hampshire, State University of Iowa, payload experiments; Douglas Aircraft Company, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General Corporation, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.

Key Spacecraft Personnel		Affiliation
PS	F.B. McDonald	NASA-GSFC
PM	P.G. Marcotte	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Electrostatic Analyzer	PI	J.H. Wolfe	NASA-ARC
Fluxgate Magnetometer	PI	L.J.I. Cahill, Jr.	University of Minnesota
Trapped Particles	PI	J.A. Van Allen	University of Iowa
	OI	L.A. Frank	University of Iowa
	CO	H. Kiel	University of Iowa
C.R - Scint+DBL Scint Telemetry	PI	F.B. McDonald	NASA-GSFC
0.1-10MeV Prot+Elec Scintillator	PI	L.R. Davis	NASA-GSFC
	OI	J.M. Williamson	NASA-GSFC
Solar Aspect Sensor	PI	J.S. Albus	NASA-GSFC
Electrolytic Timer Experiment	PI	J.N. Libbey	NASA-GSFC
Solar Cell Damage Experiment	PI	G.W. Longanecker	NASA-GSFC

SIGMA 7
(Mercury-Atlas 8)

Launch Vehicle – Atlas D similar to Mercury-Atlas 7, but with baffle injection engines and hypergolic ignition system.

Spacecraft Description – "Sigma 7" weighed approximately 3000 pounds at orbital insertion; the capsule was 6 feet in diameter at the base and 9 feet, 6 inches high.

Project Objectives – Same as Mercury-Atlas 7. The flight was scheduled for six orbits with recovery in the Pacific Ocean.

Spacecraft Payload – Astronaut Walter M. Schirra, Jr., plus major capsule systems similar to Mercury-Atlas 7. The attitude control system was modified to allow use of low-thrust jets in manual modes and two HF antennas were mounted on the retrorocket package. Two scientific experiments were carried: nine ablative material samples laminated onto the cylindrical neck of the spacecraft for evaluation of re-entry heating effects and two radiation-sensitive emulsion packs mounted on each side of the astronaut's couch to study primary cosmic radiation and search for rare particles. The hand-held 35mm camera employed five filters to be evaluated for possible use in the Tiros and Nimbus programs.

Test Results – Sigma 7 was launched into orbit from Cape Canaveral on October 3, 1962. The mission went the full six orbits, took nine hours, 13 minutes and was termed a "text book flight" by Astronaut Schirra. The spacecraft landed some 9000 yards from the planned impact point 275 miles northeast of Midway Island. Schirra stayed with the capsule as it was hoisted on board the USS Kearsarge, then blew the hatch and emerged feeling "great". Attitude control system fuel consumption, which plagued both the Glenn and Carpenter flights, was not a problem as 78 percent of the fuel supply remained in both automatic and manual tanks at re-entry, thus allowing use of automatic control during re-entry. To conserve fuel Schirra spent 118 minutes in full drifting flight during the fourth and fifth orbits (with a drift rate of less than one degree per second) and 18 minutes in limited drift during the third orbit. On the first orbit the astronaut spent considerable time adjusting the pressure suit coolant flow rate to reach the proper temperature. On the third and fifth orbits he ate from tubes of beef, vegetables, and peaches. Shirra observed the same luminous particles at sunrise and sunset as had his U.S. predecessors.

Major Participants – Same as Mercury-Atlas 7.

RANGER V

Launch Vehicle – Atlas-Agena B, with a modified Atlas D (360,000-pound-thrust) first stage and a 15,000-pound-thrust Agena B second stage. Liftoff weight, approximately 275,000 pounds; total height, 102 feet; base diameter, 10 feet.

Spacecraft Description – Ranger V's spherical lunar capsule and retrorocket were mounted on a hexagonal base. A silvered sheet encased the solid propellant retrorocket to provide thermal control; two solar panels and a high-gain antenna extended from the base. The spacecraft weighed 755 pounds and in orbital configuration was 10¼ feet high and 17 feet across the panels.

Project Objectives – Rough land an instrumented capsule on the moon, obtain television pictures of the lunar surface, study gamma radiation and radar reflectivity of the lunar surface, continue engineering development of lunar and interplanetary spacecraft. Ranger V was the last of three U.S. lunar impact missions scheduled for 1962.

Spacecraft Payload – Spacecraft systems included a solid-stage digital computer and sequencer, monopropellant midcourse correction motor, six solar sensors, earth sensor, gyroscopes, cold nitrogen gas jets, omnidirectional and high-gain antennas, 3-watt transmitter, 8680 solar cells and a 25-pound silver-zinc battery. The lunar capsule contained a highly sensitive seismometer, amplifier, six silver/cadmium batteries, 50 milliwatt transmitter, temperature-sensitive voltage control oscillator and a turnstile antenna. This instrument package floated in a layer of Freon within a balsa wood sphere. A radar altimeter was carried to initiate capsule separation and ignite the 5080-pound-thrust retrorocket, as well as to measure reflectivity as the spacecraft approached the moon. The spacecraft's television-telescope system was designed to take lunar photographs from an altitude of 2600 miles down to 15 miles. A gamma ray spectrometer was contained in a 12-inch ball mounted on a telescoping boom six feet from the spacecraft.

Test Results – Ranger V was launched from Cape Canaveral on October 18, 1962. The spacecraft was successfully injected from a parking orbit into lunar trajectory by the Agena B. Due to an unknown malfunction Ranger V failed to receive solar power; battery power supply ran down after 8 hours, 44 minutes rendering the vehicle useless. The spacecraft passed within 450 miles of the moon (without midcourse correction) and continued on into solar orbit.

Major Participants – NASA Jet Propulsion Laboratory, California Institute of Technology, spacecraft design, integration and tracking; Aeronutronic, lunar capsule; Hercules Powder Company, capsule retrorocket; USAF Systems Command, launch management; General Dynamics/Astronautics, Atlas prime contractor; Rocketdyne, Atlas propulsion; General Electric Company and Burroughs Corporation, Atlas guidance system; Lockheed Missiles and Space Company, Agena prime contractor; Bell Aerospace Company, Agena propulsion; Space Technology Laboratories, Inc., Atlas and Agena guidance equations.

Key Spacecraft Personnel		Affiliation
PM	James D. Burke	JPL
PS	Harold W. Washburn	JPL
MG	N. William Cunningham	

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	G.P. Kuiper	University of Arizona
Gamma Ray Experiment	PI	J.R. Arnold	University of California, San Diego
Radar Altimeter	PI	W.E. Brown	NASA-JPL
Seismometer	PI	F. Press	Massachusetts Institute of Technology

EXPLORER XV

Launch Vehicle – Delta, same as Explorer XIV.

Spacecraft Description – Spacecraft configuration was identical to Explorer XIV.

Project Objectives – Explorer XV (S-3B) was designed to study the location, composition and decay rate of the artificial radiation belt created by the July 9, 1962, U.S. high altitude nuclear explosion over the Pacific Ocean.

Spacecraft Payload – The spacecraft's systems were basically the same as Explorer XIV's since the satellite was a backup flight model of that earlier spacecraft. The power supply system, however, was modified to cut off for eight hours whenever total voltage fell below 11.9 volts and the solar cells were shielded with 60 mil glass. The experiment payload included: 1) directional, omnidirectional and background electron energy distribution detectors, 2) electron and proton omnidirectional detectors originally designed for Project Relay, 3) directional electron angular distribution detectors, 4) directional electron detector also designed for Relay, 5) ion-electron detector, 6) two-core fluxgate magnetometer, 7) n-on-p solar cells shielded with various thicknesses of sapphire.

Test Results – Explorer XV was launched from Cape Canaveral on October 27, 1962, into an orbit ranging from 194 to 10,760 miles. The spacecraft's despin device apparently failed, causing the vehicle to spin at approximately 60 rpm rather than the programmed 10 rpm. The excessive spin rate was expected to effect some experiment results although considerable useful data was being transmitted.

Major Participants – NASA Goddard Space Flight Center, project management, payload experiments; Bell Telephone Laboratories, payload experiments, Delta guidance system; University of California at San Diego and University of New Hampshire, payload experiments; Douglas Aircraft Company, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General Corporation, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion.

Key Spacecraft Personnel		Affiliation
PM	J.W. Townsend	NOAA
PS	W.N. Hess	NOAA-ERL

Experiment	Experiment Personnel		Affiliation
Electron Energy Distribution	PI	W.L. Brown	Bell Telephone Laboratories
	OI	U.D. Desai	NASA-GSFC
Omni+Directional (E/5, .5 P 40-110)	PI	G.E. McIlwain	University of California, San Diego
Angular Distribution	PI	W.L. Brown	Bell Telephone Laboratories
	OI	U.D. Desai	NASA-GSFC
Combined with 62-059A-D2	PI	C.E. McIlwain	University of California, San Diego
0.1-10MeV Prot+Elec Scintillator	PI	L.R. Davis	NASA-GSFC
	OI	J.M. Williamson	NASA-GSFC
Fluxgate Magnetometer	PI	L.J. Cahill, Jr.	University of Minnesota

RELAY I

Launch Vehicle – First use of improved Delta, see Explorer XVII. Liftoff weight, approximately 114,000 pounds; height, 87 feet; base diameter, 8 feet.

Spacecraft Description – 172-pound octagon tapered at one end to fit within Delta fairing; body 29 inches in diameter at base, 32 inches high. 18-inch wide-band antenna extended from small end and four monopole telemetry antennas extended from opposite end. All eight sides covered by solar cells, ends covered with coated mylar.

Project Objectives – Test intercontinental microwave communication by low-altitude active repeater satellite, measure energy levels of space radiation in orbital path, determine extent of radiation damage to solar cells and electronic components.

Spacecraft Payload – Redundant wideband transponders included 10-watt traveling wave tubes, received on 1727 mc, transmitted on 4170 mc. Two-way telephone and other narrowband traffic received on 1723.3 and 1726.6 mc and transmitted on 4165 and 4175 mc. TT&C system included redundant command receivers, subcarrier demodulators, command decoders and telemetry transmitters. 8215 p-on-n solar cells with 0.06-inch quartz coating charged nickel/cadmium battery power supply. Spin stabilized attitude control system employed magnetic torquing coil, fluid precession damper, sun aspect sensor and horizon scanner. Thermal control maintained by aluminized mylar shutter system vane at the broad end. Experiments: 1) 30 p-on-n and n-on-p solar cells, shielded and unshielded, including silicon and gallium-arsenide samples, 2) six diodes, 3) six radiation detectors.

Project Results – Relay I was launched from Cape Canaveral on December 13, 1962 into an orbit ranging from 819 to 4612 miles with a 47.5-degree inclination. Malfunction of the voltage regulator switch in the number one transponder caused an abnormal power drain, preventing operation of the communication system until January 3. Use of the number two transponder with certain command sequence changes since that date permitted Relay I to complete its mission objectives. Over 500 communication tests and demonstrations between stations in Maine, New Jersey, California, Great Britain, France, Italy and Brazil have been performed, and extensive radiation data returned.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management; Radio Corporation of America, spacecraft prime contractor; Space Technology Laboratories, systems coordination and planning, test station operation; U. of Iowa, radiation experiment; Bell Telephone Laboratories, radiation experiment, Delta guidance system; Douglas, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion.

Experiment	Experiment Personnel	Affiliation
Solar Cell Radiation Damage	PI R.C. Waddel	NASA-GSFC
Charged Particle Detectors	PI W.L. Brown	Bell Telephone Laboratories
Proton-Electron Counters	PI C.E. McIlwain	University of California, San Diego
	OI R.W. Fillius	University of California, San Diego

EXPLORER XVI

Launch Vehicle – Solid propellant Scout with four stages: 1) Algol IIA, 86,000-pound-thrust, 2) Castor, 64,000-pound-thrust, 3) Antares, 23,000-pound-thrust, 4) Altair, 3000-pound-thrust. Liftoff weight, 36,600 pounds; height, 72 feet; base diameter, 40 inches.

Spacecraft Description – Payload experiments mounted around Scout fourth stage. Total weight in orbit, 222 pounds; diameter, 24 inches; length, 76 inches.

Project Objectives – Direct measurement of micrometeoroid puncture hazard to structural skin samples, measurement of particles with different momentum, performance comparison of shielded and unshielded solar cells. Third launch in S-55 micrometeoroid satellite series. S-55, launched June 30, 1961, failed to orbit; S-55A (Explorer XIII orbited August 25, 1961, but re-entered after 2½ days.)

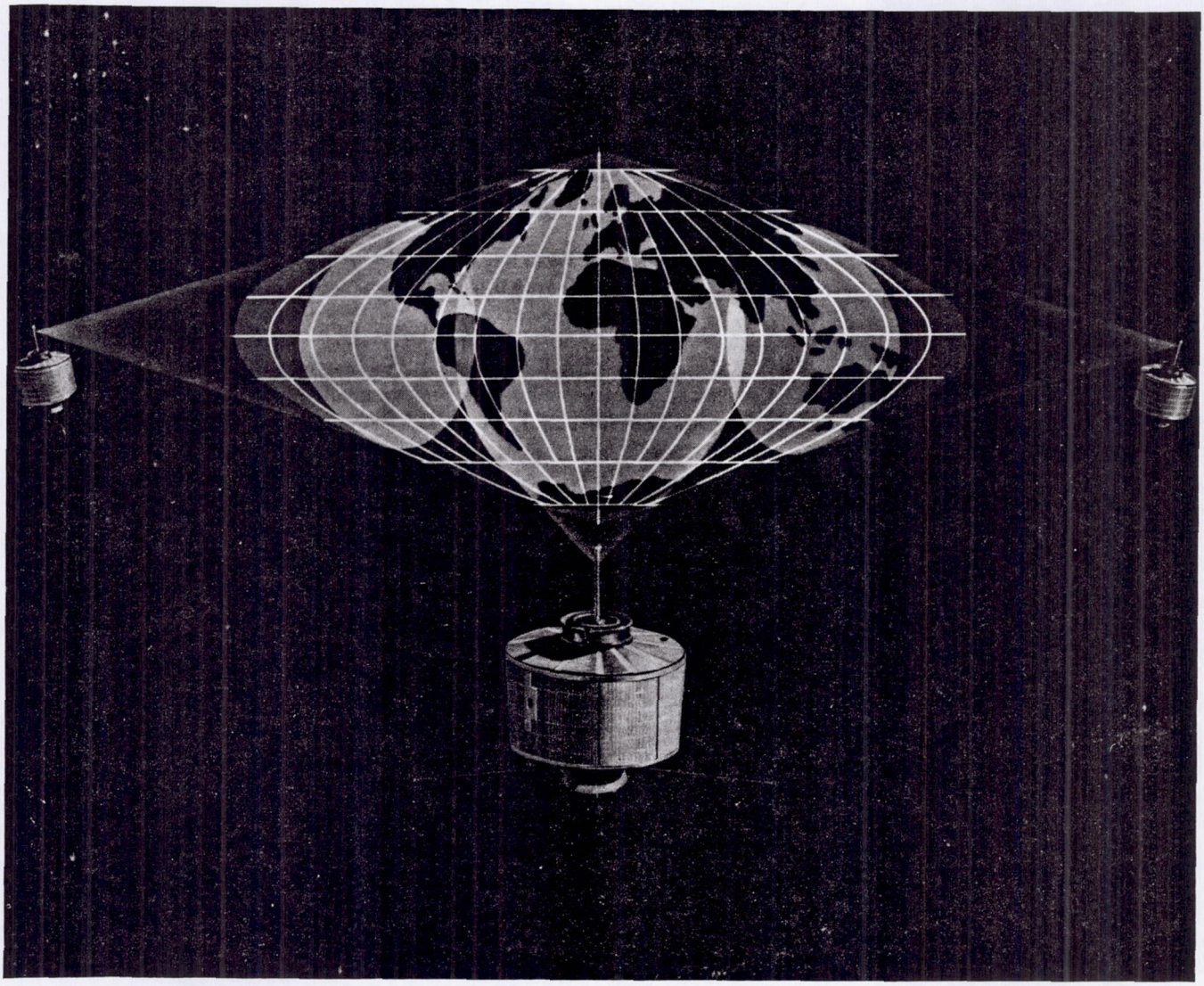
Spacecraft Payload – Six experiments: 1) 160 pressurized annealed beryllium/copper half-cylinder detectors with wall thickness from 0.001 to 0.005 inches, 2) 60 triangular foil gauge detectors mounted beneath stainless steel skin samples, 3) 46 copper wire grids wound on melamine cards, 4) two cadmium-sulfide cells mounted in aluminized glass flasks and covered with aluminized mylar sheet, 5) piezoelectric crystal impact detecting transducers, 6) five groups of p-on-n solar cells with unshielded 0.006-inch glass shielded and 3/16-inch fused silica shielded samples. Spacecraft systems: two independent data-storage, command readout PDM/FM/AM telemeters on 136.20 and 136.86 mc; beacon on 136.86 mc powered by mercury batteries; four whip antennas mounted on the nose section; nickel/cadmium battery power supply recharged by solar cells.

Project Results – Explorer XVI was launched on December 16, 1962 from Wallops Island and placed in an orbit ranging from 466 to 733 miles with an inclination of 52 degrees. Preliminary results as of March 2 yielded a puncture rate for the 0.001-inch detectors of 0.034 puncture/sq ft/day, based on 24 punctures. The 0.002-inch material had been punctured 10 times for a rate of 0.02 puncture/sq ft/day.

Major Participants – NASA Langley Research Center, spacecraft and launch vehicle management, payload experiments; NASA Goddard Space Flight Center and Lewis Research Center, payload experiments; Ling-Temco-Vought, Scout prime contractor; Aerojet-General, first stage propulsion; Thiokol, second stage propulsion; Allegany Ballistics Laboratory, third and fourth stage propulsion; Honeywell, Scout guidance system.

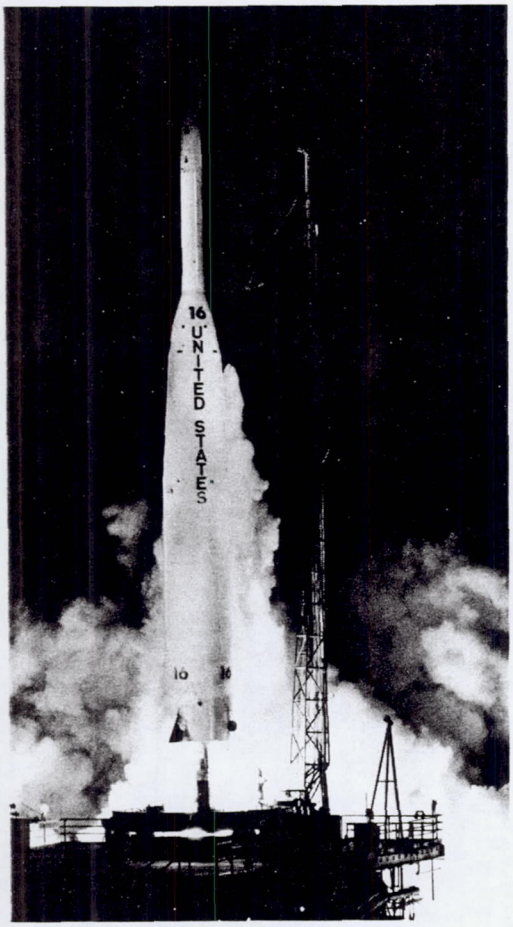
Experiment	Experiment Personnel	Affiliation
Pressurized Cells	PI C.A. Gurtler	NASA-LARC
Grid Detectors	PI E.H. Davison	NASA-LARC
Copper Wire Card	PI L. Secretan	NASA-LARC
Micrometeorite Detector	PI A.G. Beswick	NASA-LARC
Cadmium Sulphide Cell	PI L. Secretan	NASA-LARC

1963



Early concept of global communication satellite system using Syncom satellites.

SYNCOM I



Delta 16 launched into orbit the first synchronous communications satellite, Syncom 1.

Launch Vehicle – Improved Delta, similar to Explorer XVII.

Spacecraft Description – Cylinder 28 inches in diameter, 15½ inches high. Apogee motor nozzle protruded from one end, communication antennas from other end. Weight in orbit, 86 pounds.

Project Objectives – First test of communication satellite in 24-hour orbit; development of synchronous satellite injection, attitude and period control, transportable ground facilities.

Spacecraft Payload – Communication system employed redundant transponders with 2-watt traveling wave tubes. Signals received on two frequencies near 7360 mc, retransmitted on 1815 mc. Slotted dipole antenna radiated 25-degree pancake beam perpendicular to the satellite's spin axis. Syncom I was capable of transmitting one two-way telephone or 16 one-way teletype messages. 3840 solar cells charged nickel-cadmium battery power supply. On-board solid propellant apogee motor was designed to be fired to change Syncom I's orbit from elliptical to circular at an altitude of 22,300 miles. Hydrogen peroxide jets to position the satellite over the proper longitude and nitrogen jets to align the spin axis were carried, plus a second jet system of each type for station keeping.

Project Results – Syncom I was launched February 14, 1963 from Cape Canaveral. Initial communication tests conducted from the USNS Kingsport off Nigeria were successful. All contact with the spacecraft was lost, however, 20 seconds after a ground command was given to fire the apogee motor. Using search patterns based on data from the Kingsport's range and range rate system, the Boyden Observatory at Bloemfontein, South Africa sighted Syncom I on March 1. The spacecraft's initial orbit was computed to be 21,242 to 23,004 miles, with a period of 23 hours, 46.5 minutes. Attempts to re-establish communication contact with Syncom I have failed.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management; Hughes, spacecraft prime contractor; Thiokol, apogee motor contractor; USA Satellite Communications Agency, Bendix, land and sea terminals; Space Technology Laboratories, range and range rate system; Douglas, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.

Key Spacecraft Personnel	Affiliation
PM R.J. Darcey	NASA-GSFC

EXPLORER XVII

Launch Vehicle – Delta, with Thor DM-21 first stage (170,000-pound-thrust), liquid propellant 7500-pound-thrust second stage with tank lengthened three feet to extend burning time to 160 seconds, solid propellant third stage (3000-pound-thrust). Improved "600" radio guidance system, 125 pounds lighter than original Delta system. Liftoff weight, 114,000 pounds; height, 90 feet; base diameter, 8 feet.

Spacecraft Description – 35-inch pressurized stainless steel sphere with turnstile antenna array; weight, 405 pounds.

Project Objectives – Measure density, composition, pressure and temperature of the earth's atmosphere.

Spacecraft Payload – S-6 payload experiment instrumentation: two neutral mass spectrometers, four vacuum (pressure) gauges, two electrostatic probes. Explorer XVII was spun up to approximately 90 rpm prior to injection into orbit, carried a spin axis aspect system with either the sun or moon, and the earth as references. Other spacecraft systems included two independent command receivers, a solid-state PCM/PM telemetry system for realtime readout on ground command and 150 pounds of silver-zinc batteries designed to provide 100 watts for 70 hours of operation.

Project Results – Explorer XVII was launched from Cape Canaveral on April 3, 1963 and injected into a 158 to 570-mile orbit with an inclination of 57 degrees. All experiments were operating satisfactorily, and included the discovery of a belt of neutral helium around earth.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, payload experiments; Budd Company, spacecraft shell; Douglas, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.

Key Spacecraft Personnel		Affiliation
PM	N.W. Spencer	NASA-GSFC
CO	J.E. Cooley	NASA-GSFC
CO	H.E. Lagow	NASA-GSFC
SC	R.F. Fellows	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Mass Spectrometer	PI	C.A. Reber	NASA-GSFC
	CO	B. Zucker	Computer Sciences Corporation
Electrostatic Probes	PI	L.H. Brace	NASA-GSFC
	OI	N.W. Spencer	NASA-GSFC
Pressure Gauge	PI	G.P. Newton	NASA-GSFC

TELSTAR II

Launch Vehicle – Improved three-stage Delta, see Explorer XVII.

Spacecraft Description – 34.5-inch aluminum sphere covered with solar cell patches; helical antenna extended from top of spacecraft; weight, 175 pounds.

Project Objectives – Similar to Telstar I: to conduct wideband communication experiments between the satellite, the BTL ground station at Andover, Maine, and other U.S. and foreign stations. Additional emphasis was placed on studying the effects of natural and artificial radiation on communication satellites.

Spacecraft Payload – Wideband communication system designed to receive on 6390 mc, retransmit on 4170 mc with an output of 2¼ watts through a traveling wave tube. PCM/FM/AM telemetry transmitted on either 136 or 4080 mc. Dual command receivers controlled communication and telemetry systems. One command decoder utilized evacuated rather than gas-filled transistors (radiation-damaged transistors in one or both command decoders were identified as the cause of Telstar I's malfunction). Two microwave equatorial antennas received and transmitted communication and telemetry signals and the helical antenna handled telemetry, command and beacon signals, 3600 solar cells charged nickel-cadmium batteries. Radiation experiments included: four silicon diode detectors, one electron detector in the 3/4-2 MEV range with a gold "scatter" dome to absorb low-energy electrons, and three proton detectors in the 2-25, above 17 and above 40 MEV ranges; three solar cells shielded with different thicknesses of sapphire and seven silicon transistors, six specially fabricated for radiation sensitivity and one pre-irradiated.

Project Results – Telstar II was launched from Cape Canaveral on May 7, 1963 and injected into an orbit ranging from 604 to 6713 miles – the 17th consecutive success for the Delta launch vehicle. Initial transmission tests were conducted on the fourth orbit. Both color and black and white television was successfully transmitted to Great Britain and France during the tenth orbit.

Major Participants – Bell Telephone Laboratories, project management, spacecraft, U.S. ground station, Delta guidance system; NASA Goddard Space Flight Center, launch vehicle management, tracking services; Douglas, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion.

MERCURY FAITH 7
(Mercury-Atlas 9)

Launch Vehicle – Modified 360,000-pound-thrust Atlas D (130-D). Lift-off weight, 260,000 pounds; height, including capsule and 16-foot escape tower, 93 feet; base diameter, 10 feet.

Spacecraft Description – Conical body with cylindrical neck at top of the "Faith 7" capsule; 6 feet in diameter at the base and 9 feet, 6 inches high. Titanium skin covered the body, ablative fiberglass heat shield and retro-rocket package were attached to the base of the spacecraft. Approximate weight in orbit, 3000 pounds.

Project Objectives – Study effects of 22-orbit flight on the astronaut; verify that man can function in space as a primary spacecraft system for an extended period of time; evaluate performance of the astronaut with a Mercury spacecraft modified for a 22-orbit mission. Mercury Faith 7 experiments included: aeromedical studies, flashing beacon experiment, dim light phenomenon photographs, horizon definition experiments, radiation measurements, tethered balloon experiment, infrared weather photographs, television system operation, cabin environmental temperature study, HF antenna test, ground light experiment, window attenuation evaluation and white patch temperature experiment.

Spacecraft Payload – Astronaut L. Gordon Cooper, Jr.; automatic stabilization and control system with two backup systems, manual-mechanical and manual-electrical (fly-by-wire), fuel supply increased to 66 pounds; 100 per cent oxygen environmental control system; HF/UHF communication system, C- and S-band radar beacons, UHF telemetry, UHF recovery beacons; five 3000 watt-hour batteries and one backup 1500 watt-hour battery; pilot support couch and restraint system, pressure suit, aeromedical monitor system, 2376 calories of low-residue food included experimental dehydrated food and drink; drogue, main and reserve parachutes, rubberized fiberglass impact skirt; survival equipment and life raft. Experiment apparatus included: 10-pound ejectable sphere with two flashing xenon lights, 35 and 70 mm cameras with special film, 30-inch ejectable balloon, slow-scan television system.

Project Results – Mercury Faith 7 was launched from Cape Canaveral on May 15, 1963 into an orbit ranging from 100 to 166 miles. After 22 orbits and 34 hours, 20 minutes, the capsule impacted near Midway Island, 7000 yards from the USS Kearsarge recovery carrier. Insertion into orbit was the most accurate in the Mercury program to date as the Atlas imparted a capsule velocity of 25,716 fps, only 1 fps higher than planned. Cooper slept for 7½ hours, from the 10th to the 14th orbit. Fuel consumption was no problem as much of the mission was spent in drifting flight. The flashing light experiment was ejected on the 3rd orbit and finally spotted at night on

orbit 5. TV photos of the capsule interior were poor because of the lighting conditions, but photos of land masses taken out the window were good. A 3-million-candlepower light in South Africa was easily identified, in fact, Cooper could even see his hometown in Texas and other cities around the world. Two attempts to deploy the balloon experiment failed, however. The luminous particles first observed by John Glenn were also noted by the astronaut and the various photographic experiments carried out. The flight was near-perfect through the 19th orbit when the first of two malfunctions occurred, an apparent failure in the automatic sequencer system for re-entry indicated the astronaut would have to manually perform the retrofire sequence. Then on the 22nd orbit, less than 30 minutes from retrofire, both inverters failed in the automatic system requiring Cooper to go to fly-by-wire control throughout re-entry. The drogue parachute was deployed manually at 42,000 feet and the main parachute deployed automatically at 10,000 feet. The mission ended with the most accurate Mercury landing to date and with Cooper in good physical condition.

Major Participants – NASA Manned Spacecraft Center, project management; NASA Goddard Space Flight Center, tracking, data acquisition; McDonnell, prime spacecraft contractor; Honeywell, stabilization and control system; Collins Radio, instrumentation and communication systems; Garrett Corporation, environmental control system; Northrop Ventura, recovery system; Lockheed Propulsion, escape rocket; USAF Space Systems Division, launch vehicle management; General Dynamics/Astronautics, Atlas prime contractor; Aerospace Corporation, Atlas systems engineering; Rocketdyne, Atlas propulsion; General Electric and Burroughs Corporation, Atlas guidance system; Space Technology Laboratories, Atlas guidance equations; Western Electric, tracking network prime contractor; U.S. Navy, recovery task force management.

TIROS VII

Launch Vehicle – Delta, see Syncom II.

Spacecraft Description – An 18-sided polygon, 42 inches in diameter and 22 inches high; weight, 297 pounds. Sides and top covered with solar cells, an 18-inch receiving antenna located on the top and four 22-inch transmitting whip antennas extend from the baseplate.

Project Objectives – Continued meteorological satellite development – launch was timed to permit Tiros VII to obtain cloud cover photographs over hurricane and typhoon breeding areas during 1963 tropical storm season. Spacecraft also intended to make infrared measurements of reflected solar and terrestrial radiation over selected spectrum ranges and return data on electron temperature and density in space.

Spacecraft Payload – Two independent camera systems each employed ½-inch vidicon tubes with a wide-angle Elgeet lens designed to photograph an area 750 miles on a side from an altitude of 400 miles. A focal plane shutter permitted pictures to be briefly stored on the tube face plate, then converted into an electronic signal which was either directly relayed to a ground station at Wallops Island, Virginia or San Nicholas Island, California, or processed onto tape for later transmission. Up to 64 pictures could be stored during each orbit. Each camera system included a tape recorder, two-watt transmitter on 235 megacycles and an electronic clock. Infrared experiments included a five-channel medium resolution scanning radiometer and two wide-angle low resolution metallic resistance thermometers. The electron temperature and density probe was similar to an experiment carried by Explorer XVII. Spacecraft systems included an infrared horizon scanner, north indicator, despin weights and spinup rockets (12 rpm optimum spin rate), magnetic attitude control coil, over 9000 solar cells, 63 nickel-cadmium batteries and two tracking beacons on 136.92 mc.

Project Results – Tiros VII was successfully launched from Cape Canaveral on June 19, 1963 and placed in near-circular orbit with a perigee of 385 miles, an apogee of 401 miles and an inclination of 58.2 degrees. Tiros VII has furnished over 30,000 useful cloud cover photographs to date, including pictures of Hurricane Ginny in her early stages in mid-October.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, medium resolution IR experiment; Radio Corporation of America, spacecraft prime contractor; U.S. Weather Bureau, data analysis and distribution; University of Wisconsin, omnidirectional IR experiment; University of Michigan, electronic temperature and density probe; Douglas, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.

Key Spacecraft Personnel		Affiliation
PM	R.M. Rados	NASA-GSFC
PS	Aerospace and Meteorology Division	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Omni Radiometer	PI	V.E. Suomi	University of Wisconsin
Scanning Radiometer	PI	J.D. Barksdale	NASA-GSFC
	CO	R.M. Rados	NASA-GSFC
Electrostatic Probe	PI	L.H. Brace	NASA-GSFC
	OI	N.W. Spencer	NASA-GSFC
Television Experiment	PI	Ness Staff	NOAA-NESS
	CO	R.M. Rados	NASA-GSFC

SYNCOM II

Launch Vehicle – Delta-Thor DM-21 first stage with 170,000-pound-thrust, liquid propellant second stage with 7500 pounds of thrust and solid propellant second stage with 7500 pounds of thrust and solid propellant 3000-pound-thrust third stage. Liftoff weight, 114,000 pounds; height, 90 feet; base diameter, 8 feet.

Spacecraft Description – Cylinder 28 inches in diameter and 15½ inches high; faced with 3840 solar cells. Apogee motor nozzle extended from one end and co-axial slotted array communication antenna from other end, with four telemetry and command whip antennas oriented normal to satellite spin axis. Weight, 86 pounds after apogee motor firing.

Project Objectives – Develop launch, injection and attitude and velocity control techniques for synchronous satellite; perform communication tests with satellite in high altitude, synchronous orbit.

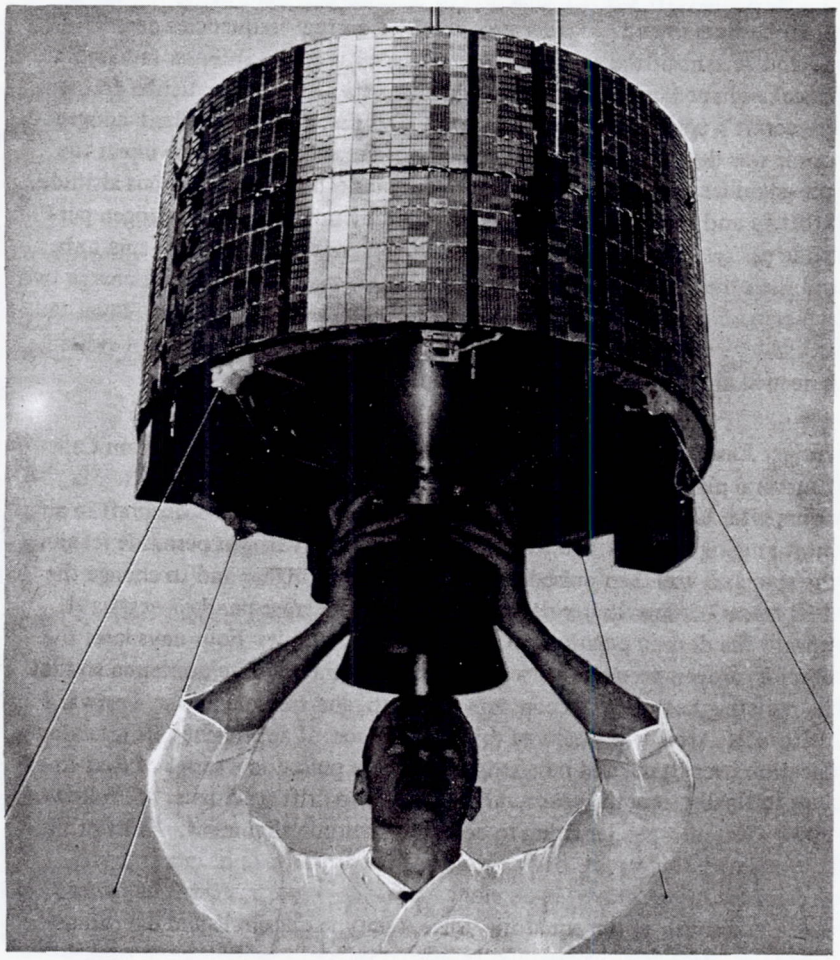
Spacecraft Payload – Syncom II employed a redundant, frequency-translation, active repeater communication system designed to handle one two-way telephone or 16 teletype channels. The dual transponders utilized 2-watt traveling wave tubes. Selection of receiver and transmitter was made by ground command. Signals were received on two frequencies near 7360 mc and retransmitted on 1815 mc. The transmitting antenna radiated a pancake-shaped beam 25 degrees wide with its plane perpendicular to the spacecraft's spin axis. The 1000-pound-thrust solid propellant apogee motor was designed to impart a velocity increase of 4696 fps to inject the spin-stabilized Syncom II into a near-circular orbit at synchronous altitude. Attitude and velocity control was provided by nitrogen and hydrogen peroxide gas systems. Each system had two jets, one parallel to the spin axis and the other perpendicular to the axis. P-on-n silicon solar cells charge two nickel-cadmium batteries. At synchronous altitude the spacecraft was in sunlight 99 percent of the time, thus no active temperature control system is needed and fewer batteries were required.

Project Results – The 19th consecutive successful Delta launch from Cape Canaveral placed Syncom II in high altitude orbit on July 26, 1963. Six hours after launch the apogee motor was fired to place the spacecraft in an orbit ranging from 21,180 to 22,632 miles. The hydrogen peroxide jet along the spin axis was then pulsed to make the apogee higher and to change the drift from 7.5 degrees per day eastward to 4.5 degrees per day westward, toward the desired position over 55 degrees longitude. Four days later the other hydrogen peroxide jet was fired to align the satellite's antenna so that its radiating beam always contacts the earth, and to increase the westward drift rate. After two weeks of drifting, Syncom II approached its intended location over Brazil and its nitrogen jets were pulsed in a series of four firings to finally slow the spacecraft to near-zero drift on August 16, followed by an axial nitrogen jet firing to complete attitude alignment. As its orbit was inclined 33 degrees to the equator, Syncom II was not in a true stationary orbit, but moved in an elongated figure eight pattern 33 degrees north and south of the equator. Voice, teletype, facsimile and data transmission tests have been successfully conducted via Syncom II between Lake-

hurst, New Jersey ground station and the terminal on board the USNS Kingsport, while the ship was moving at sea off the coast of Africa. Also, television video signals have been relayed from Lakehurst to the Telstar ground station at Andover, Maine.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management; Hughes, spacecraft prime contractor; Jet Propulsion Laboratory, apogee motor; U.S. Army Satellite Communications Agency and Bendix, land and sea terminals; TRW Space Technology Laboratories, range and range rate system; Douglas, Delta prime contractor; Rocketdyne, first stage propulsion; Aerojet-General, second stage propulsion; Allegany Ballistics Laboratory, third stage propulsion; Bell Telephone Laboratories, Delta guidance system.

Key Spacecraft Personnel	Affiliation
PM R.J. Darcey	NASA-GSFC



Syncom II's spherical apogee kick motor and nozzle are large compared with its miniaturized electronic components.

EXPLORER XVIII (IMP 1)

Launch Vehicle – Delta; employed higher thrust third stage for first time. Thor first stage with 170,000 pounds of thrust, 7500-pound-thrust liquid propellant second stage and X-258 solid propellant third stage with 5700 pounds of thrust (vs. 3000 pounds for earlier X-248 motor). Radio guidance for first and second stages, third stage spin stabilized. Total height, 90 feet.

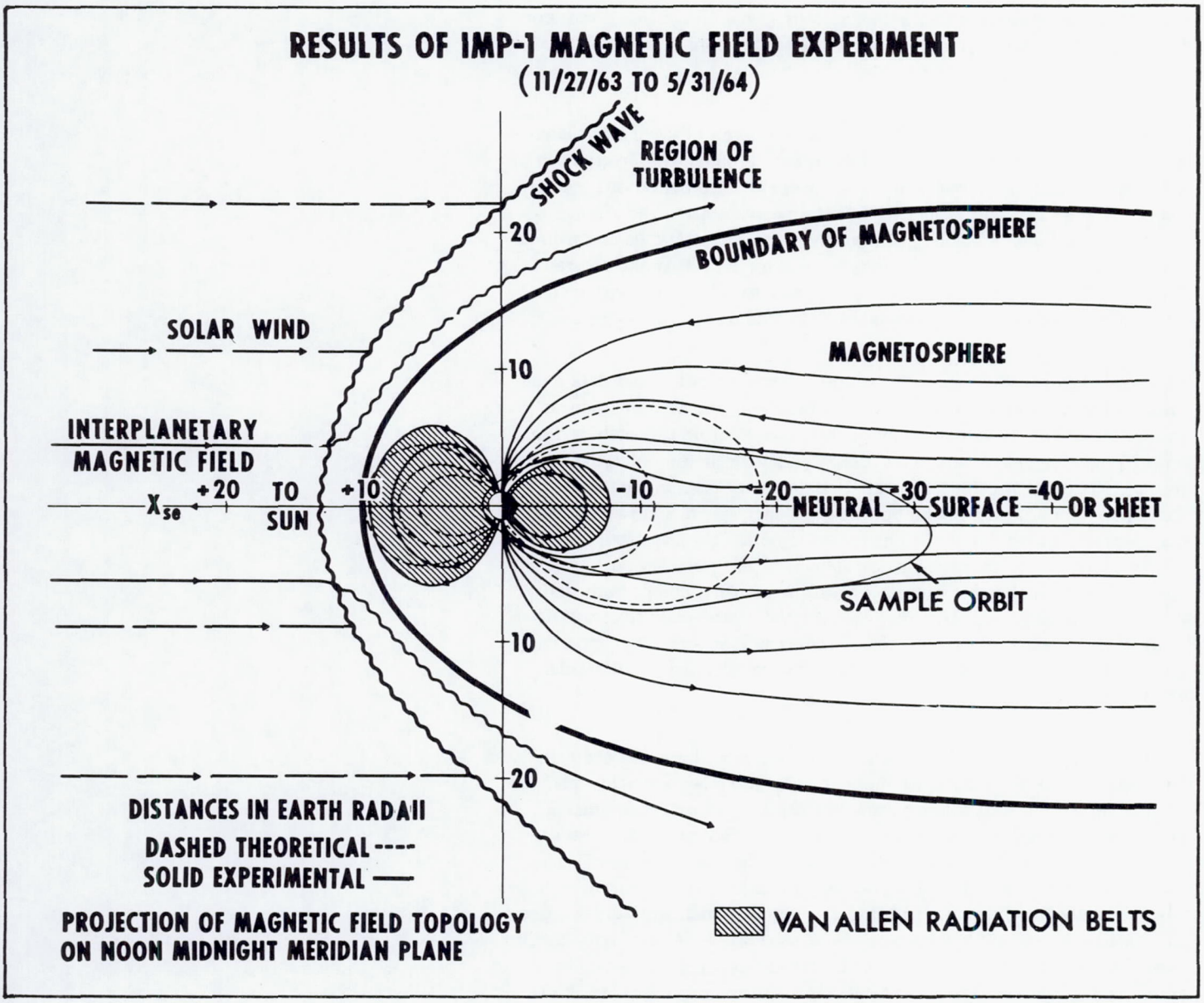
Spacecraft Description – Basic spacecraft design similar to Explorers XII, XIV, and XV. Main structure an octagon 28 inches across and 12 inches deep. Four solar paddles, four antennas, two magnetometers on seven foot booms and a magnetometer on telescopic six-foot boom extended from main structure. Weight, 138 pounds.

Project Objectives – Explorer XVIII was first of series of seven Interplanetary Monitoring Platform (IMP) satellites planned to make observations in same general area of interplanetary space over extended period of the solar cycle. Satellite's specific objectives were to measure cosmic radiation, magnetic fields and solar wind in region beyond earth's magnetic field. Information on radiation levels in interplanetary space sought for Apollo program. Explorer XVIII was also intended to provide data on the composition and depth of the side of earth's magnetosphere extending away from the sun.

Spacecraft Payload – Spacecraft systems– Communication and data handling: PFM telemetry with digital data processor for accumulation and storage of data, four-watt transmitter. Attitude control: spin stabilization, with 20 rpm design spin rate. Power supply: solar cell array of 32.8 square feet and batteries provided 38 watts. Experiment instrumentation– Rubidium-vapor magnetometer housed in 13-inch sphere and two fluxgate magnetometers were designed to measure magnetic field magnitude and direction; low-energy charged particle detector, particle telescopes (geiger counters) and ion chamber carried to measure intensity, composition and direction of both galactic and solar cosmic rays; curved-plate electrostatic analyzer, grid device which separates electrons and low-energy positive particles and a thermal ion electron experiment were intended to study solar wind.

Project Results – Explorer XVIII was launched from Cape Kennedy on November 26, 1963. Spacecraft apogee of 122,800 miles was below planned 173,000 miles, but well within parameters required for successful mission; perigee was 119 miles and inclination 33 degrees. First experiment results, released on March 12, 1964 after 2000 hours of data had been studied, revealed discovery of a region of high-energy radiation beyond Van Allen belts. The interplanetary magnetic field studies point to a spiral structure in space associated with the sun's rotation and the solar wind. A stationary shock wave 53,600 miles from earth created by interaction of the solar wind and geomagnetic field was reported. After five months in orbit Explorer XVIII entered a deep earth shadow and its equipment temperature dropped to an estimated -80 degrees C. Spacecraft transmissions finally ceased in May 1964.

Major Participants – NASA Goddard Space Flight Center, project and launch vehicle management, spacecraft prime contractor, experimenter; Universities of California (Berkeley) and Chicago, M.I.T. and NASA Ames Research Center, experimenters; Douglas, Delta prime contractor.



Explorer XVIII (IMP 1), launched by Delta 21, helped produce this new map of the Earth's magnetic field.

Key Spacecraft Personnel		Affiliation
PM	P. Butler	NASA-GSFC
PM	F.A. Carr	NASA-GSFC
PS	F.B. McDonald	NASA-GSFC
CO	A.W. Schardt	NASA Headquarters
CO	F.W. Gaetano	NASA Headquarters
CO	C.J. Creveling	NASA Headquarters
CO	D. Stewart	NASA-GSFC
CO	E.J. Pyle	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Retard Potential Analyzer, E + P	PI	G.P. Serbu	NASA-GSFC
	OI	E.J. Maier	NASA-GSFC
Fluxgate Magnetometer	PI	N.F. Ness	NASA-GSFC
Cosmic Ray Protons (R vs DE/DX)	PI	J. A. Simpson	University of Chicago
	OI	C.Y. Fan	University of Arizona
	OI	G. Gloeckler	University of Maryland
	CO	G. Lentz	University of Chicago
Cosmic Rays (E vs DE/DX)	PI	F.B. McDonald	NASA-GSFC
Energetic Particle Experiment	PI	K.A. Anderson	University of California, Berkeley
	CO	G.H. Pitt	University of California, Berkeley
Electrostatic Analyzer	PI	J.H. Wolfe	NASA-ARC
	OI	R.W. Silva	TRW Systems Group
Faraday Cup	PI	H.S. Bridge	Massachusetts Institute of Technology
Rubidium-Vapor Magnetometer	PI	N.F. Ness	NASA-GSFC
Orthogonal Geiger Mueller Counters	PI	F.B. McDonald	NASA-GSFC
	OI	G.H. Ludwig	NOAA-NESS

EXPLORER XIX

Launch Vehicle – Solid propellant Scout with four stages: 1) Algol IIA, 105,000-pound-thrust, 2) Castor, 62,000-pound-thrust, 3) Antares, 22,000-pound-thrust, and 4) Altair, 5,800-pound-thrust, employing new X-258 motor. First three stages inertial guidance, fourth stage spin stabilized. Total height, 72 feet.

Spacecraft Description – Similar to the Explorer IX balloon. Twelve-foot sphere when inflated in orbit; skin of four alternating layers of 0.0005 aluminum foil and 0.0005 mylar, with outside layer aluminum foil to reflect both sunlight and radio waves. Pattern of white dots on outer surface provided passive thermal control. Sphere weight, 18 pounds.

Project Objectives – 1) Upper atmosphere air density measurements in polar regions, density and temperature measurements at various latitudes, and 2) flight test of Scout fourth stage X-258 motor and modified third stage hydrogen peroxide control system.

Spacecraft Payload – At launch sphere was folded into tube 8.5 inches in diameter and 19 inches long mounted on front of fourth stage. After fourth stage burnout the sphere was inflated with nitrogen gas, separation spring moved spacecraft away from payload container and inflation gas allowed to escape, reducing internal pressure to that of the space environment (spacecraft structure was sufficiently rigid to maintain its shape). Tracking beacon, shielded solar cells and nickel/cadmium batteries attached to the skin. The sphere, separated into halves by a mylar equatorial insulating gap, was intended to serve as its own antenna.

Project Results – Explorer XIX was successfully launched from Point Arguello on December 19, 1963 and placed in an initial orbit ranging from 368 to 1482 miles at an inclination of 79 degrees. Satellite's tracking beacon failed, but Explorer XIX was being tracked optically to obtain long-term atmospheric density data and also to study density changes caused by solar disturbances.

Major Participants – NASA Langley Research Center, project and launch vehicle management, spacecraft prime contractor; NASA Goddard Space Flight Center and Smithsonian Astrophysical Observatory, experimenters; AF Space Systems Division, launch operations; Ling-Temco-Vought, Scout prime contractor.

Key Spacecraft Personnel		Affiliation
PM	C.W. Coffee, Jr.	NASA-LARC
PS	R.F. Fellows	NASA Headquarters
CO	G.M. Keating	NASA-LARC
SC	E.R. Schmerling	NASA Headquarters
MG	J.R. Holtz	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Nonsystematic Changes Air Density	PI	L.G. Jacchia	SAO
Systematic Changes Air Density	OI	W.J. O'Sullivan, Jr.	NASA-LARC
	OI	C.W. Coffee, Jr.	NASA-LARC
	PI	G.M. Keating	NASA-LARC

TIROS VIII

Launch Vehicle – Delta, similar to Explorer XVIII except for use of X-248 motor in third stage.

Spacecraft Description – Standard Tiros configuration – polygon with 18 sides, 42 inches in diameter and 22 inches high. Sides and top covered with solar cells, 18-inch receiving antenna located on top and four 22-inch transmitting antennas extended from the baseplate. Weight, 265 pounds.

Project Objectives – Continued meteorological satellite development; initial flight testing of the Automatic Picture Transmission (APT) camera system and ground stations. Infrared experiments were not carried this flight.

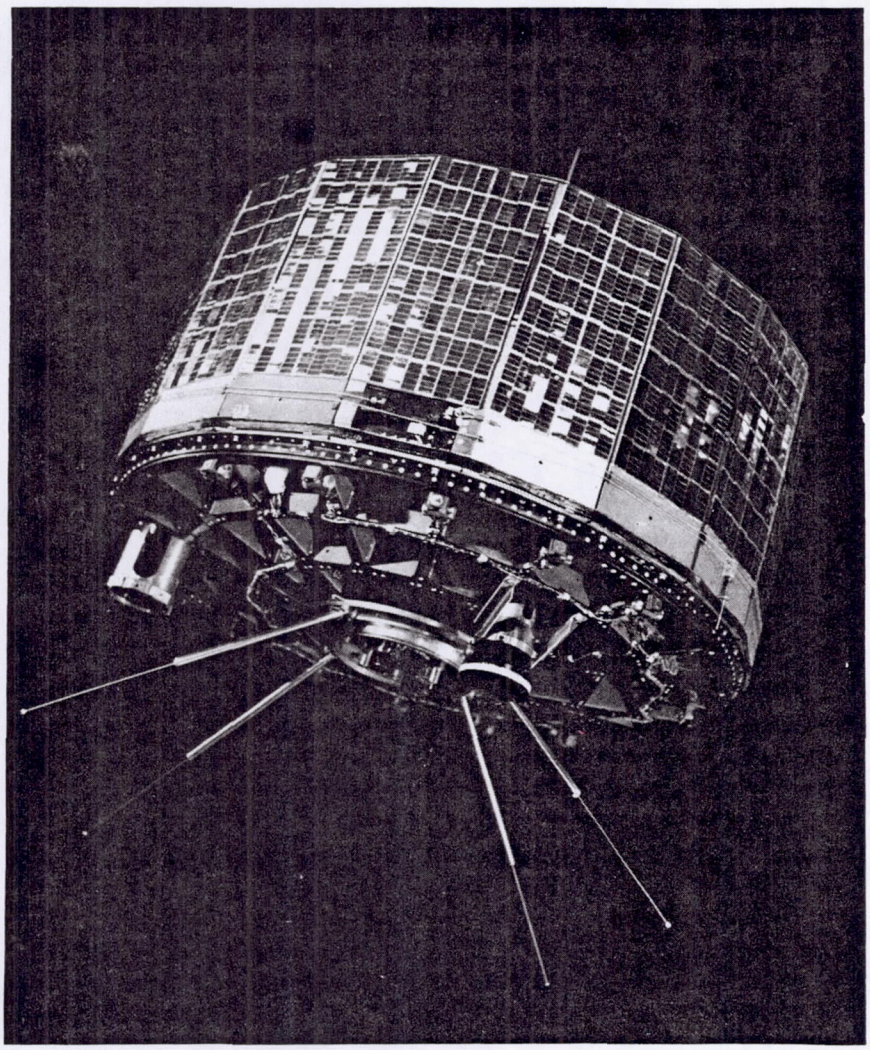
Spacecraft Payload – Spacecraft systems– Attitude control: horizon scanner, north indicator, despin weights and solid propellant spinup rockets employed to maintain optimum 12 rpm spin rate, magnetic coil to maintain orientation. Power supply: 9200 solar cells charged 63 nickel/cadmium batteries. Cameras: two independent systems, one with standard Tiros 104-degree lens and an APT camera with 108-degree lens. APT system designed to photograph maximum area of 820 miles on a side, featured 800-scan line 1-inch vidicon. APT pictures transmitted on the slow-scan principle – four lines per second – similar to that used to send radio photographs; each APT ground station intended to receive up to three pictures per orbit. Other tube a 500-scan line ½-inch vidicon used with tape recorder to store up to 32 pictures for readout to stations in Virginia, California and Alaska. Wide-angle lens designed to photograph an area 750 miles on a side.

Project Results – Tiros VIII was successfully injected into orbit on December 21, 1963. Near-circular orbit ranged from 430 to 473 miles at an inclination of 58.5 degrees. The APT experiment exceeded its planned 90-day lifetime, was pronounced a success. Some 47 inexpensive APT ground stations around the world reported good signal strength and good contrast in the cloud cover photographs. Scalloping and banding effects were noted on the received pictures, however. Both camera systems returned high quality photographs, with 90 percent of 36,000 photos usable.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; Fairchild Stratos, APT ground stations; U.S. Weather Bureau, data analysis and distribution; Douglas, Delta prime contractor.

Key Spacecraft Personnel		Affiliation
PM	R.M. Rados	NASA-GSFC
PS	Aerospace and Meteorology Division	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	Ness Staff	NOAA-NESS
Automatic Picture Transmission (APT)	PI	C.M. Hunter	NASA-GSFC

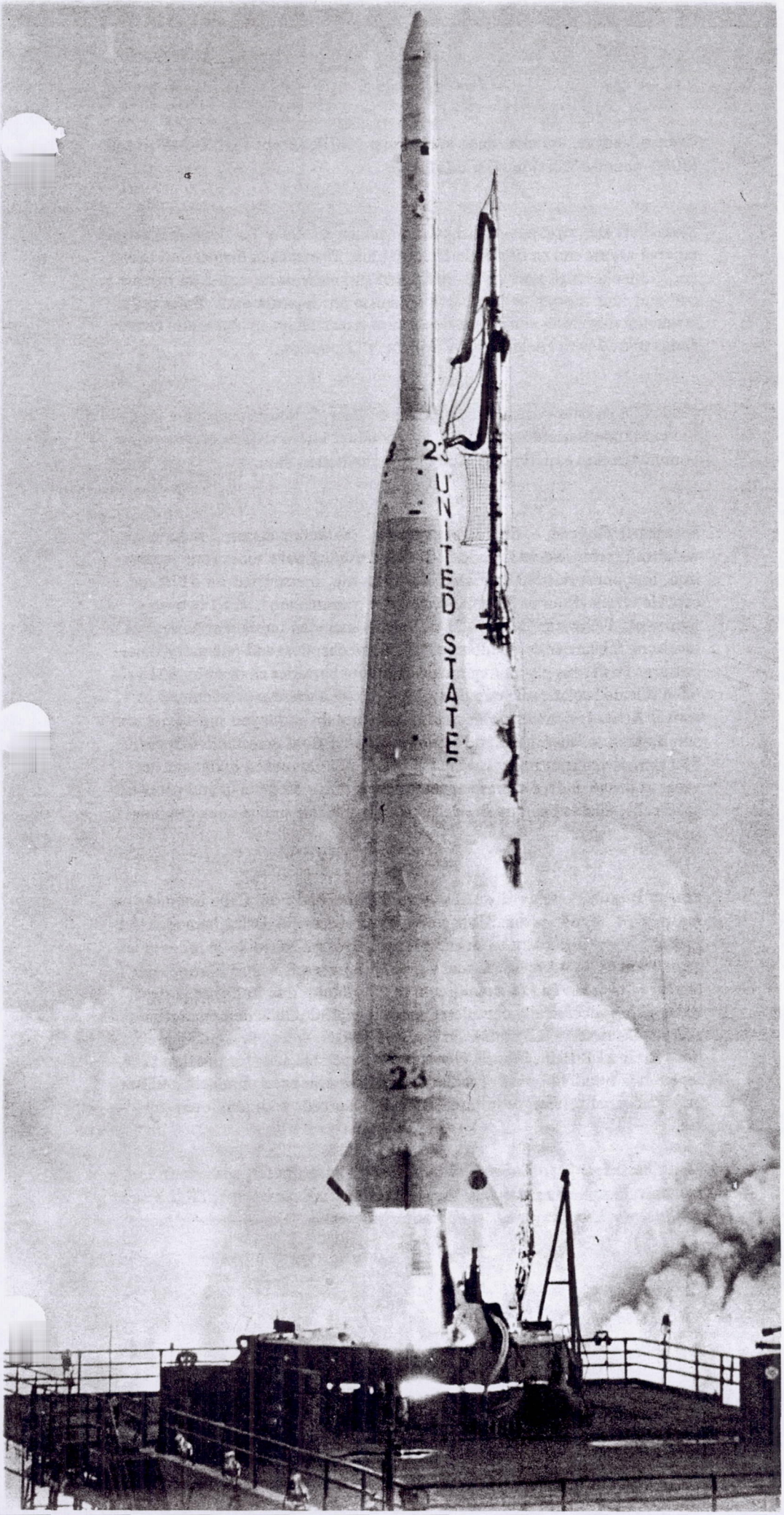


NASA G 63-3381

A new eye on the weather–Tiros VIII's automatic picture transmission system made it possible to obtain local cloud cover pictures using inexpensive ground stations.

1963

1964



On January 21, 1964 Delta 23 lifted off from its Cape Kennedy launch pad, launching Relay II into orbit.

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RELAY II

Launch Vehicle – Delta, same as Explorer XVIII, except that X-248 motor (3000-pound-thrust) used in third stage.

Spacecraft Description – Configuration similar to Relay I – octagonal prism tapered at one end to fit within Delta fairing; 29 inches in diameter at broad end, 33 inches high plus an 18-inch wideband antenna mounted on narrow end and four monopole telemetry antennas on opposite end. Solar cells covered honeycomb aluminum side panels mounted on an aluminum chassis, ends covered with coated mylar. Weight, 172 pounds.

Project Objectives – Test modifications to Relay I design; determine satellite's maximum useful operational life; conduct intercontinental microwave communication experiments; obtain space radiation data.

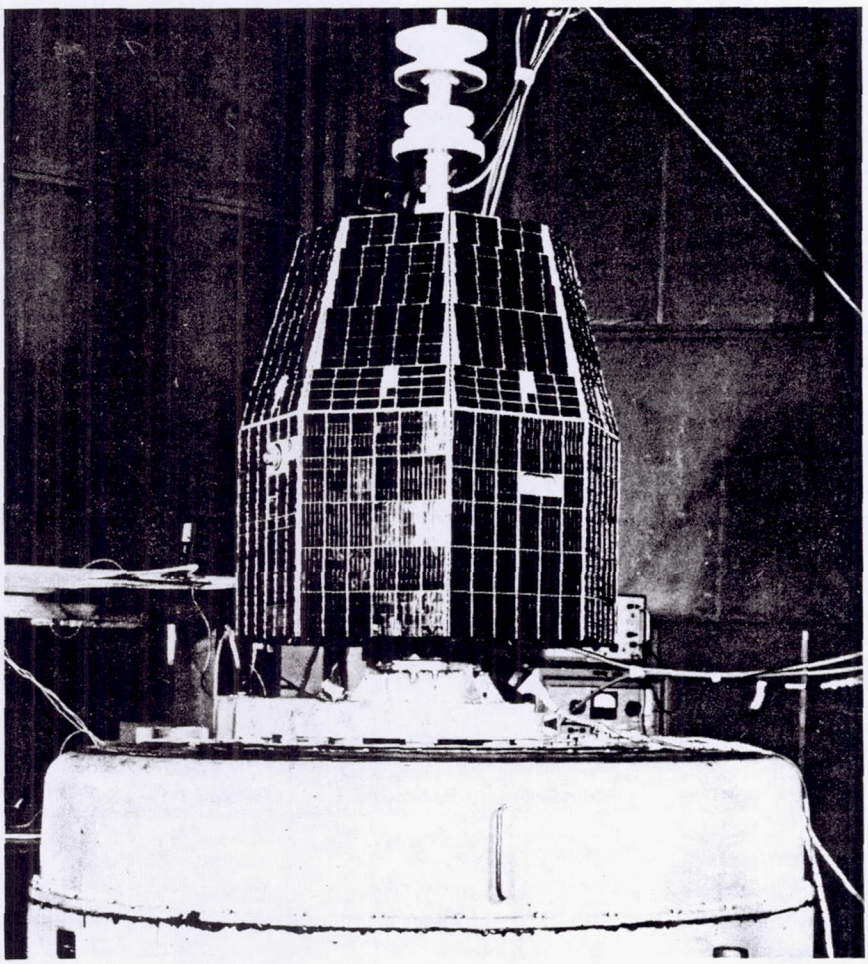
Spacecraft Payload – Spacecraft systems– Communication: redundant wideband transponders included 10-watt traveling wave tubes (one pressurized, one unpressurized), received on 1725 mc, transmitted on 4170 mc, capable of television or 300 one-way voice transmissions, or 12 two-way narrowband communication. TT&C system included redundant command receivers, subcarrier demodulators, command decoders and telemetry transmitters. Power supply: three nickel-cadmium batteries charged by 8215 n-on-p shielded solar cells were designed to provide average requirement of 45 watts. Attitude control: spin stabilization system employed sun aspect sensor, horizon scanner, magnetic torquing coil and fluid precession damper; 150 rpm design spin rate. Thermal control: aluminumized mylar shutter vanes at broad end. Experiment Instrumentation– 30 n-on-p and p-on-n solar cells, shielded and unshielded, including silicon and gallium-arsenide samples.

Project Results – Relay II was successfully launched from Cape Kennedy on January 21, 1964 – the 22nd consecutive successful Delta launch. The spacecraft was injected into an orbit ranging from 1298 to 4606 miles at an inclination of 46 degrees. Mutual visibility between U.S. and Europe was improved over Relay I to a maximum of 70 minutes due to higher perigee. Relay II has successfully completed more than 230 public demonstrations and tests between U.S. stations in Maine, New Jersey and California and stations in Great Britain, France, Germany, Italy, Brazil and, for the first time, Japan. Six hundred hours of radiation data has also been obtained, and has indicated good results for gallium-arsenide solar cells with minimum shielding.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; TRW Space Technology Laboratories, test operations; Douglas, Delta prime contractor.

Key Spacecraft Personnel		Affiliation
PM	W.S. Sunderlin	NASA-GSFC
PS	R.C. Waddel	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Solar Cell Radiation Damage	PI	R.C. Waddel	NASA-GSFC
P-N Juncture Electron, Proton Detectors	PI	W.L. Brown	Bell Telephone Laboratories
Proton-Electron Counters	PI	C.E. McIlwain	University of California, San Diego
	OI	R.W. Fillius	University of California, San Diego



Prior to shipment, Relay II undergoes vibration tests. Solar cells covered much of the 172 pound spacecraft. This orbiting electronic relay station linked continents providing telephone, data, and video communications.

1964

ECHO II

Launch Vehicle – Thor-Agena B. First stage 170,000-pound-thrust Thor; second stage 16,000-pound-thrust Agena B programmed for two burns. First stage employed radio guidance, second stage inertially guided. Total height, 86 feet.

Spacecraft Description – Sphere 135 feet in diameter after inflation in orbit. Made of 0.0035-inch mylar, with 0.00018-inch aluminum alloy foil laminated to either side and coated on both sides with alodine. Inside surface also coated with black India ink. Satellite weighed 457 pounds, including beacon and power supply system.

Project Objectives – 1) Conduct passive communication experiments – radio, teletype and facsimile tests, 2) accumulate data about spacecraft's orbital environment, 3) test slower, more controlled inflation method. U.S.S.R. communication experiments with Echo II planned under 1962 Dryden-Blagenrovov agreement for cooperative space exploration.

Spacecraft Payload – Prior to inflation, spacecraft was packed in oblate spheroid cannister, 39.6 inches in diameter and 29.3 inches deep. Seventy-two envelopes containing pyrazole crystals were positioned within Echo II in such a way that, upon ejection from the cannister into sunlight, each would gradually build up. This method was designed to take about 90 minutes for full inflation, permitting higher pressures and thus a stronger structure and better reflectivity. Two beacon transmitters were mounted opposite each other on satellite's equator, with each transmitter powered by four triangular solar cell arrays and nickel-cadmium batteries.

Project Results – Echo II was launched from Vandenberg AFB on January 25, 1964 and successfully placed in orbit with apogee of 816 miles, perigee of 642 miles and inclination of 81.5 degrees. There is some question whether the sphere was fully inflated or not, but good experiment results have been obtained and data was exchanged with the U.S.S.R.

Major Participants – NASA Goddard Space Flight Center, project management; G. T. Schjeldahl Co., spacecraft prime contractor; Grumman, spacecraft canister; Naval Research Laboratory, Naval Electronics Laboratory, Collins Radio, Lincoln Laboratory and Bell Telephone Laboratories, experimenters; NASA Lewis Research Center, launch vehicle management; AF Space Systems Division, launch operations; Douglas, Thor prime contractor; Lockheed, Agena prime contractor.

Key Spacecraft Personnel		Affiliation
PM H.L. Eaker		NASA-GSFC
Experiment	**Experiment Personnel**	**Affiliation**
Beacon Transmit	PI Unknown	Unknown
Optical (Passive)	PI Swanson	Unknown
Atmospheric Drag	PI L.G. Jacchia	SAO
Density	OI J.R. Slowey	SAO

RANGER VI

Launch Vehicle – Atlas-Agena-B. First stage 360,000-pound-thrust Atlas D, second stage 16,000-pound-thrust Agena B programmed for two burns. Atlas employed radio guidance system, Agena used inertial guidance. Total height, 104 feet.

Spacecraft Description – A 375-pound conical camera payload structure mounted on standard hexagonal Ranger bus. Payload covered by polished aluminum shroud with 13-inch opening near top for the television cameras. Bus constructed of aluminum and magnesium tubing and structural members. Electronic packages attached to each side and midcourse motor set inside structure with nozzle facing down. High-gain antenna and two solar panels hinged to spacecraft's base, and omni-directional antenna mounted on top of camera payload. With solar panels and high-gain antenna deployed, Ranger VI was 15 feet across and 10.25 feet high. Weight, 840 pounds.

Project Objectives – Spacecraft was the first of series of four Rangers intended to photograph the lunar surface during final ten minutes of flight prior to hard landing. Impact area selected was strip 20 degrees above or below lunar equator on leading edge within 10 to 40 degrees of the terminator. Ranger VI's photographs were intended to support Surveyor and Apollo programs, and to provide scientific data.

Spacecraft Payload – Spacecraft systems– Communication: 3-watt receiver-transmitter for ground commands and telemetry. Attitude control: redundant cold gas systems of six jets and one nitrogen bottle each, four primary and two secondary sun sensors, earth sensor and three gyros; all events programmed by digital central computer and sequencer. Midcourse motor: monopropellant hydrazine engine with 50 pounds of thrust for a maximum 98.5 seconds. Power supply: 4896 solar cells plus redundant silver-zinc batteries provided 200 watts. Experiment instrumentation– Television package weighed 375 pounds and included two wide-angle (F chain) and four narrow-angle cameras (P chain), camera sequencer, video combiner, two 60-watt transmitters, telemetry system and two silver-zinc batteries. All cameras had fixed focus but were designed to take photographs from 900 miles down to about one-half mile of lunar surface. Cameras employed variety of lens apertures due to uncertainty regarding moon's local lighting conditions.

Project Results – Ranger VI was launched into parking orbit from Cape Kennedy on January 30, 1964. Spacecraft was injected on lunar trajectory following second Agena burn. Sun-earth acquisition and midcourse maneuvers successfully carried out. Orientation of cameras to lunar surface was acceptable for picture quality and precluded terminal maneuver. At 19 minutes prior to impact wide-angle cameras were automatically commanded into warm-up and at 15 minutes narrow-angle cameras were switched to warm-up by ground command. The sequencers in each chain should have switched entire television system to full power at impact minus 14 minutes for F chain and impact minus ten minutes for P chain but no video signal was received. Backup ground commands transmitted from Goldstone without success. Spacecraft impacted on west side of Sea of Tranquility after 65.6 hours of flight. NASA/JPL/RCA review concluded that an unscheduled turn-on of television system for 67 seconds approximately two minutes

after launch, causing electrical arcing, was most probable explanation for failure.

Major Participants – Jet Propulsion Laboratory, project management, spacecraft prime contractor; RCA, television package; Northrop, central computer and sequencer, attitude control subsystems; NASA Lewis Research Center, launch vehicle management; NASA Goddard Space Flight Center, launch operations; General Dynamics/Astronautics, Atlas prime contractor; Lockheed, Agena prime contractor; TRW Space Technology Laboratories, launch vehicle guidance equations.

Key Spacecraft Personnel		Affiliation
PM	Harris M. Schurmeier	JPL
PS	None	
MG	N. William Cunningham	

Experiment	Experiment Personnel	Affiliation
Television Experiment	PI G.P. Kuiper	University of Arizona

BEACON EXPLORER A

Launch Vehicle – Delta, similar to Explorer XVIII, except that X-248 motor employed in third stage.

Spacecraft Description – Octagonal main body 18 inches across and 12 inches deep, made of honeycomb nylon and fiberglass. Four blade-like solar panels, each ten inches by 5.5 feet, extended from main structure and two five-foot whip antennas and two dipole antennas were mounted on the ends of opposite solar panels. Dipole antenna were also mounted on top and bottom of body. Truncated pyramid atop main body was covered with 360 fused silica reflectors. Weight, 120 pounds.

Project Objectives – Satellite was intended to transmit uncoded radio signals to a network of more than 80 ground stations in 32 countries to provide data on ionosphere: 1) behavior and electron density, 2) relationship of behavior to solar radiation and 3) geometry and distribution of irregularities. A second purpose was to conduct laser and doppler shift geodetic tracking experiments.

Spacecraft Payload – Spacecraft systems– Attitude control: solar panel erection and a despin mechanism were designed to reduce spin rate to four rpm, with spin rate to be gradually reduced to zero by magnetic despin rods in the panels. Two bar magnets were mounted inside the spacecraft shell to passively orient spacecraft along earth's magnetic field. Power supply: solar cells (twice number needed for initial power requirements) and nickel-cadmium batteries. Thermal control: vacuum insulation between instrumentation and spacecraft shell, special bank of solar cells to maintain internal temperature above 70 degrees F. Experiment instrumentation– Ionospheric experiments consisted of four signals (20, 40, 41 and 360 mc) transmitted at power levels above 100 mw to ensure good signal-to-noise ratios. Signals were to be received at simple, low-cost radio receivers throughout world. Doppler tracking experiment signals were to be transmitted on 163 and 324 mc. Pulsed ruby laser mounted on tracking telescope at Wallops Island was to have illuminated glass reflectors and reflected light's travel time used to determine satellite slant range.

Project Results – Beacon Explorer A (also identified as S-66) was launched from Cape Kennedy on March 19, 1964, but failed to reach orbit. Third stage burn lasted only 22 seconds vs. programmed 40 seconds. Circular orbit of 750 miles and inclination of 70 degrees had been planned. The failure was only the second in the Delta program and came after 22 consecutive successful flights.

Major Participants – NASA Goddard Space Flight Center, project and launch vehicle management, experimenter; Applied Physics Laboratory, Johns Hopkins University, spacecraft prime contractor; Univ. of Illinois, Pennsylvania State Univ., Stanford Univ. and NBS Central Radio Propagation Laboratory, experimenters; Douglas, Delta prime contractor.

ARIEL II

Launch Vehicle – Four-stage Scout, see Explorer XIX.

Spacecraft Description – Modified version of Ariel I, orbited in April, 1962; a cylinder 23 inches in diameter and rounded at both ends (with an ozone detector mounted on one end), 35 inches high. Four solar paddles, two inertia booms, four telemetry antennas and a 130-foot dipole antenna (reeled out following orbit) extended from the spacecraft. Spacecraft shell of fiberglass, with passive thermal control paint pattern. Weight, 150 pounds.

Project Objectives – Built by the U.S., the spacecraft carried three British experiments to measure galactic radio noise, vertical distribution of the ozone (that portion of the atmosphere created when the sun's ultraviolet radiation reacts with oxygen in the earth's atmosphere) and micrometeoroid flux.

Spacecraft Payload – Spacecraft systems– Attitude control: spin-stabilized, with yo-yo despin device to slow spin to 5 rpm. Power supply: 5400 solar cells and redundant nickel-cadmium battery packs. Communication and data handling: tape recorder, PFM telemetry and transmitter-receiver, encoder and programmer subsystems. Experiment instrumentation– Galactic noise experiment included 0.75 to 3 mc frequency range, employed 130-foot dipole and two ferrite rod loop antennas. Broadband and scanning techniques used in 2500 to 4000A wavelengths in ozone measurement experiment. Micrometeoroid impacts were measured by two aluminum foil and two mylar detectors.

Project Results – Ariel II was launched from Wallops Island March 27, 1964 and injected into an orbit ranging from 180 to 843 miles at an inclination of 52 degrees. All experiments were reported to be operating successfully. The satellite's spin rate dropped to 2.16 rpm early in June, but then increased to more than 3 rpm later in the month.

Major Participants – NASA Goddard Space Flight Center, project management; Westinghouse, spacecraft prime contractor; British National Committee on Space Research, experiment management; Univ. of Cambridge, Air Ministry Meteorological Office and Univ. of Manchester, experimenters; NASA Langley Research Center, launch vehicle management; Ling-Temco-Vought, Scout prime contractor.

Key Spacecraft Personnel		Affiliation
PM	E.W. Hymowitz	NASA-GSFC
PS	L. Dunkelman	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Galactic Radio Noise	PI	F.G. Smith	University of Cambridge
Ozone	PI	K.H. Stewart	
Micrometeoroid	PI	R.C. Jennison	University of Kent

GEMINI I

Launch Vehicle – Modified Titan II ICBM. Hypergolic liquid propellant vehicle with 430,000-pound-thrust first stage and 100,000-pound-thrust second stage; radio guidance system. Total height, 108 feet.

Spacecraft Description – Essentially a growth version of conical Mercury design. Two major assemblies – re-entry module (basic spacecraft, with 50 percent more cabin space than Mercury) with rendezvous and recovery, re-entry control and cabin sections, and adapter module with retrograde and equipment sections. Re-entry module's structure was primarily of titanium, with external skin of forward sections beryllium and cabin section hatches covered with nickel alloy. Adapter module frame utilized magnesium, aluminum and titanium, with a magnesium skin. Total height, 19 feet; weight, about 7000 pounds. For G-I mission, second stage-spacecraft separation was not programmed and the spacecraft remained attached to 10-foot diameter, 19-foot long second stage; total weight in orbit, approximately 11,400 pounds.

Project Objectives – Primary mission objectives were to check out: 1) launch vehicle-spacecraft structural compatibility, 2) launch vehicle-spacecraft launch heating conditions, 3) launch vehicle performance, 4) launch vehicle flight control system switch-over circuits, 5) launch vehicle orbital insertion accuracy, 6) spacecraft structural integrity and 7) malfunction detection system. No recovery of the unmanned spacecraft was planned.

Spacecraft Payload – Principal payload was two instrumentation pallets (in place of crew couches) which carried 400 pounds of pressure transducers, temperature sensors and accelerometers. Heat sensors monitored thermal radiation on outer window of spacecraft and sound level measurements were made inside cabin section. Electrical, coolant and communication (C-band radar beacon, phase shifter, DC-AC inverter, three C-band antennas, three telemetry transmitters and a UHF antenna) systems supported instrumentation packages. Functional systems not required for this mission were simulated with dummy packages where necessary for structural purposes, and ballast carried to duplicate normal spacecraft weight.

Project Results – Gemini I was launched from Cape Kennedy on April 8, 1964 and second stage and spacecraft injected into an orbit ranging from 99.6 to 204 miles at inclination of 33 degrees. No holds encountered during countdown. Apogee about 20 miles higher than planned as Titan II velocity 21 fps faster than programmed (but within ±25 fps tolerance). All mission objectives met and flight termed highly successful. Total of 104 measurements taken in various spacecraft sections and telemetered during first orbit. Spacecraft decayed after four days.

Major Participants – NASA Manned Spacecraft Center, project management, NASA Goddard Space Flight Center, tracking and data acquisition; McDonnell, spacecraft prime contractor; AF Space Systems Division, launch vehicle management; Martin, Titan II prime contractor.

SATURN I (SA-6)

Launch Vehicle – Saturn I, with S-I first stage (1,500,000-pound-thrust) and S-IV second stage (90,000-pound-thrust, liquid hydrogen fuel), inertial guidance system. Total height, 190 feet.

Spacecraft Description – Boilerplate Apollo command and service modules (BP-13). Command module was an aluminum structure simulating size, weight, shape and center of gravity of manned operational Apollo. Conical module was 154 inches in diameter at the base and about 11 feet high, covered with cork to prevent structure from overheating. A 120-inch escape tower structure was mounted atop the command module to support 183-inch dummy launch escape motor. Service module, an aluminum structure 154 inches in diameter and 124 inches long, was mounted beneath the command module. Service module was bolted to an insert section, which was bolted to an adapter section, which in turn remained bolted to the S-IV second stage. The Apollo payload weighed 17,000 pounds; entire Apollo-second stage weighed 37,300 pounds and was 80 feet long.

Project Objectives – Principal mission purpose was to flight-test the launch vehicle. In addition to orbiting boilerplate modules, secondary objectives included determining structural characteristics of launch escape system, launch system jettison characteristics and compatability of spacecraft R&D instrumentation and communication systems with launch vehicle systems.

Spacecraft Payload – Active command module systems for the first Apollo orbital flight included solid propellant tower jettison motor and tower separation system. Spacecraft was instrumented for 116 strain gauge, pressure and acceleration measurements and carried three telemetry systems. Redundant instrumentation batteries and launch escape system pyro and logic batteries were included. Environmental control system was designed to maintain command module ambient temperature at 80 degrees F., ±10 degrees.

Project Results – Saturn I was launched from Cape Kennedy on May 28, 1964. Payload was injected into an orbit ranging from 114 to 149 miles at an inclination of 32 degrees. Launch was sixth straight success in Saturn development program. An inboard engine shut down 23 seconds early, but deviation from planned trajectory was corrected by adaptive guidance system. The spacecraft tumbled slowing, as expected, but 28 degrees per second spin rate was faster than desired (due to venting of evaporating gas from propellant residuals through a single vent). All spacecraft systems operated as planned during countdown and flight. Telemetry was obtained from 106 measurements until end of battery life on fourth orbit. Saturn I decayed May 31 on its 50th orbit.

Major Participants – NASA Manned Spacecraft Center, spacecraft management, NASA Goddard Space Flight Center, tracking and data acquisition; North American, spacecraft prime contractor; NASA Marshall Space Flight Center, launch vehicle management; NASA J. F. Kennedy Space Center, launch operations; Chrysler, first stage prime contractor; Douglas, second stage prime contractor.

SPACE ELECTRIC ROCKET TEST (SERT) I

Spacecraft Description – Two ion thrusters programmed to operate sequentially during 46-minute, 58-second ballistic trajectory flight.

Objectives – Determine how electron-bombardment ion engines perform over long periods of time and how such prolonged operations affect other spacecraft systems. These low-thrust, high-efficiency rockets to be used to position satellites in Earth orbit or someday propel spacecraft to the distant planets.

Results – SERT I, launched July 20, 1964 at Wallops Island, Virginia, included two ion thrusters programmed to operate sequentially during the 46-minute, 58-second ballistic trajectory flight. The contact ion thruster could not be started because of a high-voltage electrical short circuit, but the electron-bombardment ion thruster was operated as expected for 31 minutes, 16 seconds. This was the first time an ion thruster had been operated in space and confirmed that high prevalence ion beams could be neutralized in space.

Major Participants – Lewis Research Center, program development; Wallops Flight Center, launch operations.

RANGER VII

Launch Vehicle – Atlas-Agena B, same as Ranger VI.

Spacecraft Description – Basic configuration remained the same as Ranger VI. Weight, 806 pounds.

Project Objectives – Second in a series of four spacecraft designed to return high resolution photographs of the lunar surface prior to impact on the moon.

Spacecraft Payload – Modifications were made to the command and control circuitry and the television telemetry system based on Ranger VI experience. Additional preventive steps were taken in thermal control, packaging, parts usage, reliability and testing.

Project Results – Ranger VII was launched from Cape Kennedy on July 28, 1964 and placed in parking orbit. The spacecraft was injected on a lunar trajectory after second Agena ignition. Midcourse motor was fired for 50 seconds the second day; terminal correction was not required. Camera systems were turned on as scheduled and at 1120 miles altitude, 16 minutes and 40 seconds from impact, the first of 4316 high quality photographs were taken. About 400 wide-angle and 3900 narrow-angle pictures were returned with the first photo covering an area 400 miles square and the last photograph, taken 1000 feet above the lunar surface, showing an area 60 x 100 feet with about 1.5 foot resolution. Impact, at 5850 mph, was in the Sea of Clouds at 10.7 degrees S, 20.7 degrees W. Total flight time, 68 hours and 35.55 minutes; flight distance, 243,665 miles. The initial photographs released showed amazing detail, with resolutions up to 1000 times greater than previous earth-based efforts.

Major Participants – Jet Propulsion Laboratory, project management, spacecraft prime contractor; RCA, television package; Northrop, central computer and sequencer, attitude control subsystems; NASA Lewis Research Center, launch vehicle management; NASA Goddard Space Flight Center, launch operations; General Dynamics/Astronautics, Atlas prime contractor; Lockheed, Agena prime contractor; TRW Space Technology Laboratories, launch vehicle guidance equations.

Key Spacecraft Personnel		Affiliation
PM	Harris M. Schurmeier	JPL
PS	None	
MG	N. William Cunningham	

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	G.P. Kuiper	University of Arizona
	OI	R.L. Heacock	NASA-JPL
	OI	E.M. Shoemaker	California Institute of Technology
	OI	H.C. Urey	University of California, San Diego
	OI	E.A. Whitaker	University of Arizona

SYNCOM III

Launch Vehicle – First Thrust-Augmented Delta (TAD) launch. Thor first stage employed three strap-on solid propellant motors to provide total thrust of 333,550 pounds. Normal 7500-pound-thrust second stage and 5700-pound thrust solid propellant third stage with X-258 motor used. First and second stages radio guided, third stage spin stabilized. Height, 90 feet.

Spacecraft Description – Cylinder faced with solar cells, 28 inches in diameter and 15.5 inches high. Apogee motor extended from one end and four whip antennas from the other. Weight in orbit, 86 pounds.

Project Objectives – First attempt to orbit a truly synchronous satellite (orbits of earlier Syncoms were inclined to the equator). Satellite was intended to be placed over equator at 180° longitude, to conduct communication tests between the Philippines, USNS Kingsport and Camp Roberts, California, and to provide live television coverage of Olympic Games in Tokyo.

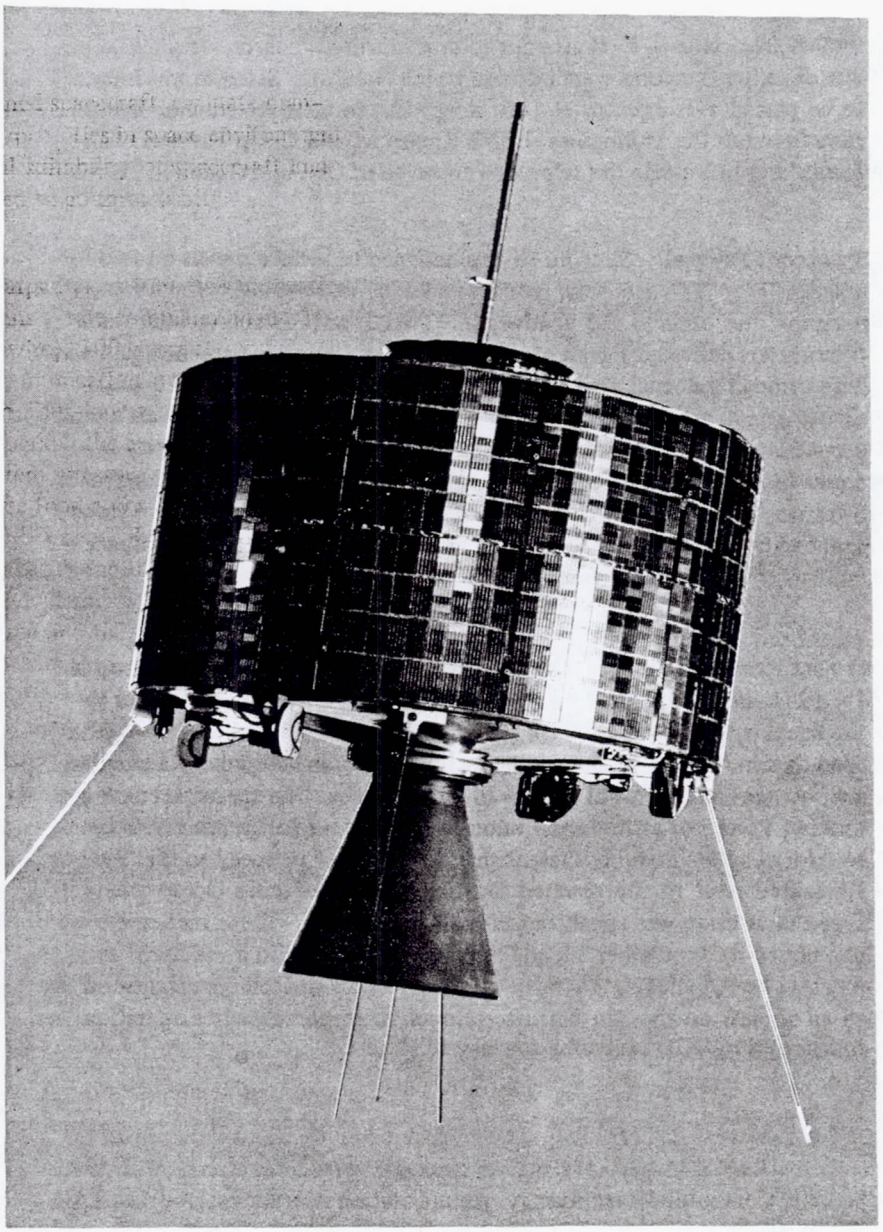
Spacecraft Payload – Syncom III was designed to receive signals on two frequencies near 7360 mc. One receiver had a 13 mc bandwidth for TV transmissions, the other 5 mc bandwidth. Two 2-watt traveling-wave tube transmitters delivered signals at about 1815 mc. Receiving antenna gain was 2 db through a slotted dipole, receiver noise figure was 10 db and coaxial slotted array transmitting antenna designed for 6 db gain. Spacecraft's solid propellant apogee kick motor intended to provide a 4696 fps velocity increase to inject Syncom into circular orbit. Attitude and velocity control in orbit was maintained by dual hydrogen peroxide gas jet systems. Power supplied by 3840 n-on-p solar cells and nickel-cadmium batteries. Spacecraft thermal control achieved by passive means.

Project Results – Syncom III was launched from Cape Kennedy on August 19, 1964 and injected into an elliptical orbit inclined about 16 degrees to the equator, following a third stage yaw maneuver. Apogee motor was then fired to remove most of the remaining inclination and to provide a circular, near-synchronous orbit of 22,164 to 22,312 miles. The spacecraft next carried out a series of attitude and velocity maneuvers to align itself with the equator at an inclination of less than 1° and to slow its speed so that Syncom III drifted west to the planned location over the Pacific Ocean where its speed at altitude was synchronized with the earth's. These maneuvers were completed by September 23, and Syncom III was used in a variety of communication tests, including TV relay of the Olympics and teletype transmissions to an aircraft on the San Francisco-Honolulu route. Satellite operation was transferred to DOD beginning January 1, 1965.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management; Hughes, spacecraft prime contractor; U.S. Army Satellite Communications Agency, ground station operations; Douglas, TAD prime contractor.

Key Spacecraft Personnel		Affiliation
PM	R.J. Darcey	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Radio Beacon	PI	A.V. Darosa	Stanford University
	OI	P.C. Yuen	University of Hawaii
	OI	T.H. Rofloes	University of Hawaii



Syncom, NASA's experimental synchronous communications satellite, was launched by Delta to provide live television coverage of the Olympic games in Tokyo, as well as to conduct communications tests between the Philippines.

EXPLORER XX
(Ionosphere Explorer A)

Launch Vehicle – Scout, with four solid propellant stages: 1) Algol IIA, 105,000-pound-thrust, 2) Castor, 55,000-pound-thrust, 3) Antares, 15,000-pound-thrust, 4) Altair, 3100-pound-thrust (X-248 motor). First three stages inertially guided, fourth stage spin stabilized. Height, 72 feet.

Spacecraft Description – Cylinder with truncated cone on bottom end and cone, with 4-inch experiment sphere on top, mounted on other end. Diameter, 26 inches; height, 46.5 inches. Three dipole sounding antennas extended from mid-section, two 62 feet in length and one 122 feet long, and turnstile telemetry antennas were mounted on the base of the satellite. Conical surfaces covered by solar cells. Weight, 97 pounds.

Project Objectives – Satellite intended to make radio soundings of upper ionosphere at six fixed frequencies as part of NASA's Topside Sounder program. This research program also employs swept-frequency Alouette I, orbited in 1962, plus ground sounding stations. Explorer XX was planned to return data on horizontal irregularities in electron distribution in the ionosphere to complement Alouette's vertical readings. A second objective was to obtain cosmic noise measurements.

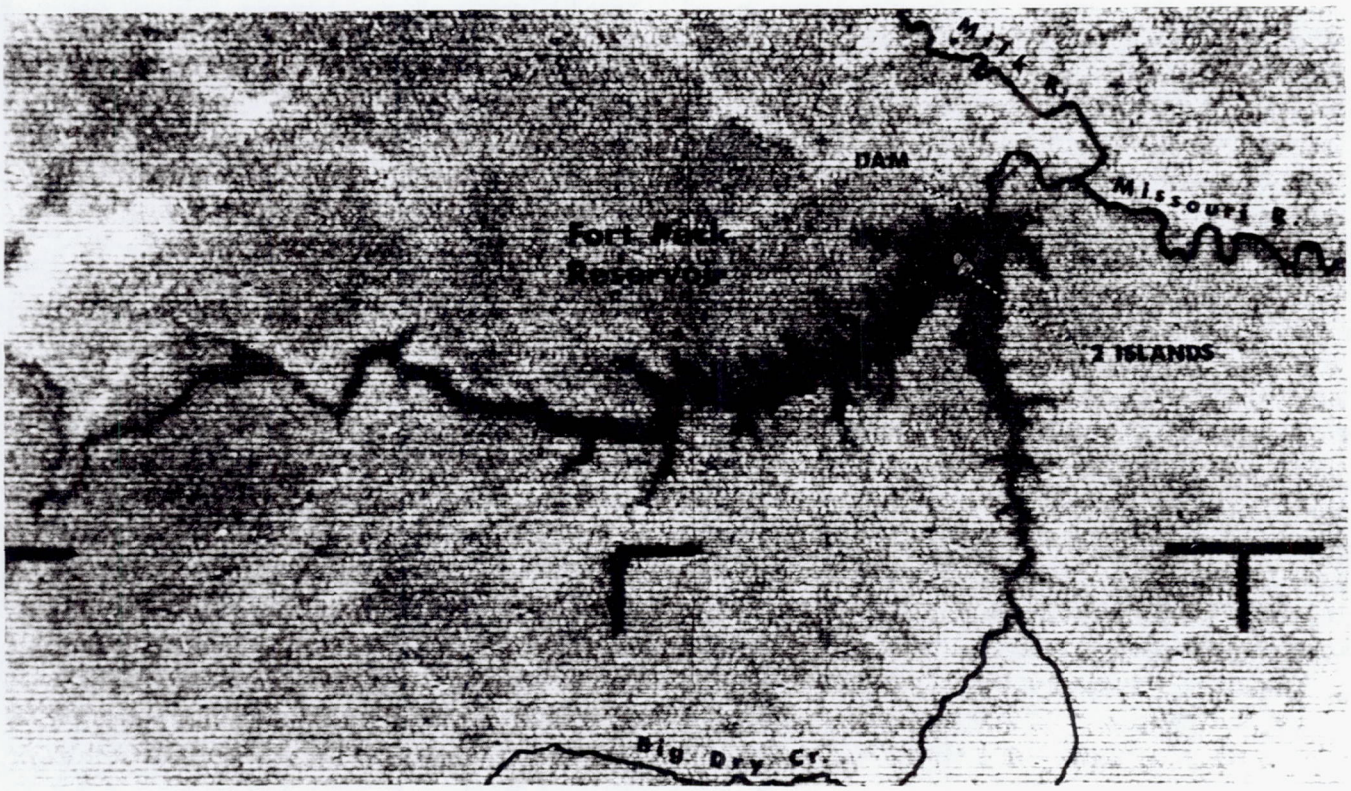
Spacecraft Payload – Sounding experiment included six 8- to 45-watt transmitters pulsed in sequence between 1.5 and 7.2 mc. Ion mass spectrometer carried to furnish ion density and temperature data. Satellite designed to spin at 2.2 rpm with sounding antennas fully extended. Power supplied by 2400 p-on-n solar cells and nickel-cadmium batteries. Experiment telemetry transmitted on 136.350 mc.

Project Results – Explorer XX was launched from Vandenberg AFB on August 25, 1964, and placed in an orbit from 540 to 625 miles at 80° inclination. An average of four to five hours of soundings per day have been obtained. Important new data was being collected on the existence of sheets of field-aligned ionization irregularities extending well above spacecraft apogee in the polar regions. Other observations included the ducting of HF radio pulses along magnetic field-aligned irregularities between opposite hemispheres, and fixed-frequency data on plasma resonance effects in the ionosphere.

Major Participants – NASA Goddard Space Flight Center, project management; Airborne Instruments Laboratory, spacecraft prime contractor; NBS Central Radio Propagation Laboratory and University College of London, experimenters; NASA Langley Research Center, launch vehicle management; USAF Space Systems Division, launch operations; Ling-Temco-Vought, Scount prime contractor.

Key Spacecraft Personnel		Affiliation
PM	J.E. Jackson	NASA-GSFC
SC	A.G. Opp	NASA Headquarters
MG	M.J. Aucremanne	NASA Headquarters
PS	J.E. Jackson	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Fixed Frequency Ionosonde	PI	R.W. Knecht	National Bureau of Standards
	OI	W. Calvert	Lockheed Palo Alto
	OI	T.E. Van Zandt	NOAA-ERL
	OI	R.B. Norton	NOAA-ERL
	OI	J.M. Warnock	NOAA
Ion Probe	PI	R.L.F. Boyd	University College of London
	OI	A.P. Willmore	University of Birmingham
Cosmic Noise	PI	R.G. Stone	NASA-GSFC



Nimbus I weather satellite took this photograph of Fort Peck Reservoir on the Missouri River.

NIMBUS I

Launch Vehicle – Thor-Agena B: Thor first stage – 170,000 pounds of thrust, Agena B second stage – 16,000 pounds of thrust. First stage, radio guidance; second stage, inertial guidance. Height, 86 feet.

Spacecraft Description – Lower ring section housed meteorological sensors and electronics, upper hexagonal section contained attitude control system and had two solar panels attached to its sides. Two sections were connected by a magnesium truss; lower section 57 inches in diameter, spacecraft 118 inches high and 134 inches across solar panels. Weight, 830 pounds.

Project Objectives – Initial flight test of Nimbus spacecraft; provide improved photographs of local cloud conditions by an automatic picture transmission (APT) system, first used by Tiros VIII; and evaluate advanced vidicon camera system for daylight coverage and high-resolution infrared radiometer system for night-time cloud cover observation.

Spacecraft Payload – Three 1-inch vidicon cameras with 800-line resolution designed to scan a 750,000 square mile area from 575-mile retrograde circular orbit, with delayed readout of up to 192 photos or direct readout by APT system. High-resolution infrared radiometer operated in 3.4 to 4.2 micron region. Earth-stabilization attitude control system employed two horizon scanners, coarse sun sensors, yaw gyro, reaction wheels and eight freon gas jets. Louvers on both sections utilized for thermal control. Power supplied by 10,500 n-on-p solar cells and nickel-cadmium batteries.

Project Results – Nimbus I was launched from Vandenberg AFB on August 28, 1964. Premature Agena cut off resulted in an elliptical orbit of 263 to 579 miles at 80° inclination, rather than intended circular orbit. Spacecraft's solar panel drive failed September 23, after Nimbus I had returned more than 27,000 excellent photos. Vidicon camera systems spotted five hurricanes and two typhoons in photographing 70 percent of the world each day. APT system supplied daytime photos to more than 60 low-cost ground stations. Radiometer photos were remarkably clear – comparable to previous medium-resolution Tiros pictures – and covered a 12,500 square mile area. Photo of the Antarctic taken at midnight showed four black dots determined as mountains at the edge of the continent. Further analysis indicated a strong possibility of volcanic activity in the mountains. Nimbus I's stabilization system worked well during its operational lifetime.

Major Participants – NASA Goddard Space Flight Center, spacecraft management; General Electric, spacecraft prime contractor; RCA, cameras and solar power system; ITT Industrial Laboratories, radiometer system; Fairchild-Hiller, APT ground stations; U.S. Weather Bureau, data handling; NASA Lewis Research Center, launch vehicle management; USAF Space Systems Division, launch operations; Douglas, Thor prime contractor; Lockheed, Agena prime contractor.

Key Spacecraft Personnel		Affiliation
PM	H. Press	NASA-GSFC
PS	W.P. Nordberg	NASA-GSFC
CO	G.J. Delio	NASA-GSFC
CO	P.J. Crossfield	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel	Affiliation
AVCS	PI G.L. Burdett	NASA-GSFC
APT	PI C.M. Hunter	NASA-GSFC
HRIR	PI L.L. Foshee	USA Electronics Command

OGO I

Launch Vehicle – Atlas-Agena B: Atlas D first stage (360,000-pound-thrust) and Agena B second stage (16,000-pound-thrust). First stage, radio guidance; second stage, inertial guidance. Height, 107 feet.

Spacecraft Description – Aluminum main body, 67 inches long and 31 inches square. Two solar panels mounted on sides of the body, with solar-oriented experiment package (SOEP) on each panel and a 30-foot radio astronomy antenna deployed from one SOEP. Two 22-foot and four 6-foot experiment booms extended from ends of the body as did two attitude control booms, antenna boom and orbital plane experiment package (OPEP) boom facing forward in the orbital plane. Fully deployed, satellite was 59 feet long and 20 feet across solar panels. Weight, 1046 pounds.

Project Objectives – First in new series of standardized spacecraft capable of conducting many related experiments. OGO I carried 20 experiments, more than any previous U.S. satellite. Spacecraft's highly elliptical orbit was planned to permit correlated investigations of geophysical and solar phenomena in the earth's atmosphere and magnetosphere, and in interplanetary space.

Spacecraft Payload – Scientific instrumentation totaled 190 pounds and included experiments from nine universities and seven government laboratories: rubidium vapor, triaxial search coil and fluxgate magnetometers and VLF noise and propagation experiment – mounted on the long booms; omnidirectional trapped radiation counters, ion chamber, spherical ion and electron trap and interplanetary dust sensors – short booms; solar cosmic rays, solar plasma Faraday cup, positron (low-energy positive electrons), radio astronomy and Gegenschein photometry experiments – SOEP's and main body; solar plasma electrostatic analyzer – SOEP, OPEP and main body; trapped radiation scintillation counter, cosmic ray spectra and fluxes, planar ion and electron trap and atmospheric mass spectrum experiments – in the two OPEPs and main body; cosmic ray isotopic abundance, trapped radiation electron spectrometer and geocoronal Lyman-Alpha scattering experiments – main body; and radio propagation experiment – transmitter in main body plus antennas on two of the short booms. Spacecraft systems included a communication and data handling system to store up to 86 million bits of data with transmission rates up to 128,000 bits per second. Earth-stabilization attitude control system employed horizon scanner, two sun sensors, argon gas jets and reaction wheels. Gyro control and a wabble gear drive maintained OPEPs in required direction, and wabble gear drive used to align solar panels with the sun. Louvers on the sides and one end of main body provided thermal control. Power supplied by more than 32,000 solar cells and nickel-cadmium batteries.

Project Results – OGO I was successfully launched from Cape Kennedy on September 5, 1964 and placed in an orbit of 175 to 98,287 miles (vs. nominal apogee of 92,689 miles) at 31° inclination. Two experiment booms failed to deploy properly, however, and one of these booms obscured horizon scanner's view of earth. As a result, spacecraft attitude could not be earth oriented and OGO I remained spin stabilized at 5 rpm. The solar panels were turned to a more favorable sun angle and all 20 experiments were able

to provide data. The value of the experiment data varied, but useful information was being received from all experiments. OGO I, together with data from Explorer XXI, has indicated the source of much of the Van Allen belt's high-energy radiation as the solar wind – entering the magnetosphere through weak field lines in the magnetosphere's tail on the side of the earth opposite the sun.

Major Participants – NASA Goddard Space Flight Center, spacecraft management; TRW Space Technology Laboratories, spacecraft prime contractor; NASA Lewis Research Center, launch vehicle management; USAF Space Systems Division, launch operations; General Dynamics/Astronautics, Atlas prime contractor; Lockheed, Agena prime contractor.

Key Spacecraft Personnel		Affiliation
PM	W.E. Scull	NASA-GSFC
PS	G.H. Ludwig	NOAA-NESS
SC	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
Triax Search Coil Magnetometer	PI	E.J. Smith	NASA-JPL
	OI	R.E. Holzer	University of California, Los Angeles
RB Vapor + Fluxgate Magnetometer	PI	J.P. Heppner	NASA-GSFC
	OI	B.G. Ledley	NASA-GSFC
	OI	M. Sugiura	NASA-GSFC
	OI	R.M. Campbell	Unknown
	OI	T.L. Skillman	NASA-GSFC
Spherical Electrostatic Analyzer	PI	R.C. Sagalyn	USAF Geophysical Laboratory
	OI	M. Smiddy	USAF Geophysical Laboratory
Planar Ion-Electron Trap	PI	E.C. Whipple	NOAA-ERL
	OI	B.E. Troy, Jr.	US Naval Research Laboratory
Radio Propagation	PI	J.K. Hargreaves	NOAA-ERL
	OI	R.S. Lawrence	University of Lancaster
	OI	R.B. Fritz	NOAA-ERL
	OI	O.K. Garriott	NASA-JSC
Ion Mass Spectrometer	PI	H.A. Taylor	NASA-GSFC
	OI	H. Brinton	NASA-GSFC
	OI	R. Pickett	NASA-GSFC
Interplanetary Dust Particles	PI	J. L. Bohn	Temple University
	OI	W.M. Alexander	Baylor University
	CO	C.S. Nilsson	Flinders University of Southern Australia
VLF Receiver	PI	R.A. Helliwell	Stanford University
	OI	J.J. Angerami	Stanford University
	OI	L.H. Rorden	Devlco Incorporated

Experiment	Experiment Personnel		Affiliation
Radio Astro, .2-.4MC, 2-4MC	PI	F.T. Haddock	University of Michigan
Geo Lyman Alpha	PI	P.W. Mange	US Naval Research Laboratory
Gegenschein Photometry	PI	C.L. Wolff	NASA-GSFC
	OI	K.L. Hallam	NASA-GSFC
	OI	S.P. Wyatt	University of Illinois
Solar Cosmic Rays	PI	K.A. Anderson	University of California, Berkeley
	OI	G.H. Pitt	University of California, Berkeley
Electrostatic Analyzer	PI	J.H. Wolfe	NASA-ARC
Faraday Cup	PI	H.S. Bridge	Massachusetts Institute of Technology
	OI	A.M. Bonetti	Institute of Physics
	OI	B. Rossi	Massachusetts Institute of Technology
	OI	A.J. Lazarus	Massachusetts Institute of Technology
	OI	F. Scherb	University of Wisconsin
	OI	V.M. Vasyliunas	MPI-Aeronomy
Positron Search and Gamma Ray	PI	T.L. Cline	NASA-GSFC
	OI	E.W. Hones, Jr.	Los Alamos Science Laboratories
0.1-10 MeV Proton + Electron Scintillator	PI	A. Konradi	NASA-JSC
	OI	L.R. Davis	NASA-GSFC
	OI	R.A. Hoffman	NASA-GSFC
	OI	J.M. Williamson	NASA-GSFC
Cosmic Ray Isotopic Abundance	PI	F.B. McDonald	NASA-GSFC
	OI	G.H. Ludwig	NOAA-NESS
Cosmic Ray Spectra and Fluxes	PI	J.A. Simpson	University of Chicago
	CO	G. Lentz	University of Chicago
	OI	C.Y. Fan	University of Arizona
Geiger Mueller Detector (Trapped Rad, Proton)	PI	J.A. Van Allen	University of Iowa
	OI	L.A. Frank	University of Iowa
	CO	H. Kiel	University of Iowa
Ion Chamber	PI	J.R. Winckler	University of Minnesota
	OI	S.R. Kane	University of California, Berkeley
	OI	R.L. Arnoldy	University of New Hampshire
Electron Spectrometer	PI	J.R. Winckler	University of Minnesota
	OI	K.A. Pfitzer	McDonnell Douglas Corporation
	OI	R.L. Arnoldy	University of New Hampshire

SATURN I
(SA-7)

Launch Vehicle – Saturn I, with 1,504,000-pound-thrust S-I first stage, 90,000-pound-thrust S-IV second stage and an instrument unit. ST-124 inertial guidance platform was fully employed for the first time. Total height, 190 feet.

Spacecraft Description – Boilerplate Apollo command and service modules (BP-15). Command module was an aluminum structure simulating size, weight, shape and center of gravity of manned operational Apollo spacecraft. Conical structure was 154 inches in diameter at the base and 140 inches high, covered with cork insulation to prevent module from overheating. A 120-inch escape tower structure was mounted atop command module to support 185-inch launch escape motor. Service module, an aluminum structure 154 inches in diameter and 141 inches long, was mounted beneath the command module. Service module was bolted to an insert section, which was attached to an adapter section, which remained with the instrument unit and S-IV second stage. The Apollo boilerplate weighed 17,200 pounds; entire Apollo-instrument unit-second stage payload weighed 36,700 pounds in orbit and was 80 feet long.

Project Objectives – Flight test Saturn I, test spacecraft design and structure during atmospheric flight, demonstrate launch vehicle-spacecraft compatibility and test spacecraft launch escape system.

Spacecraft Payload – Spacecraft was instrumented for 133 measurements such as heat rates, temperatures, aerodynamics and static loads. Command module environmental system designed to maintain internal temperature at $80^{\circ}F \pm 10^{\circ}$. Spacecraft electrical power supplied by redundant instrumentation, launch escape system pyro and logic batteries. Live pitch control and 155,000-pound-thrust launch escape motors included in the escape system.

Project Results – Saturn I was launched from Cape Kennedy on September 18, 1964. Payload was injected into an orbit of 115 miles to 141 miles at an inclination of 32°. All objectives achieved; launch was the seventh consecutive success in the Saturn development program. Spacecraft decayed September 22 after 59 orbits. Telemetry was obtained from 131 separate and continuous measurements.

Major Participants – NASA Manned Spacecraft Center, spacecraft management; North American, spacecraft prime contractor; NASA Marshall Space Flight Center, launch vehicle management; NASA Kennedy Space Center, launch operations; Chrysler, first stage prime contractor; Douglas, second stage prime contractor.

Key Spacecraft Personnel		Affiliation
PM	P. Butler	NASA-GSFC
PS	F.B. McDonald	NASA-GSFC
CO	C.J. Creveling	NASA-GSFC
CO	D. Stewart	NASA-GSFC
CO	E.J. Pyle	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Retard Potential Analyzer, E + P	PI	G.P. Serbu	NASA-GSFC
	OI	E.J. Mater	NASA-GSFC
Fluxgate Magnetometer	PI	N.F. Ness	NASA-GSFC
Cosmic Ray Protons (R vs DE/DX)	PI	J.A. Simpson	University of Chicago
	OI	C.Y. Fan	University of Arizona
	OI	G. Gloeckler	University of Maryland
	PG	G. Lentz	University of Chicago
Cosmic Rays (E vs DE/DX)	PI	F.B. McDonald	NASA-GSFC
Total Ionization Experiment	PI	K.A. Anderson	University of California, Berkeley
Electrostatic Analyzer	PI	J.H. Wolfe	NASA-ARC
Faraday Cup	PI	H.S. Bridge	Massachusetts Institute of Technology
	OI	J.H. Binsack	Massachusetts Institute of Technology
Rubidium-Vapor Magnetometer	PI	N.F. Ness	NASA-GSFC
Orthogonal Geiger Mueller Counter	PI	F.B. McDonald	NASA-GSFC
	OI	G.H. Ludwig	NOAA-NESS

EXPLORER XXI (IMP 2)

Launch Vehicle – Delta: Thor first stage with 170,000 pounds of thrust, 7500-pound-thrust second stage and solid propellant third stage with 5700 pounds of thrust. First and second stages radio guided, third stage spin stabilized. Height, 90 feet.

Spacecraft Description – Similar to Explorer XVIII (IMP 1). Satellite's main structure an octagon 8 inches high and 28 inches across. A magnetometer sphere was mounted on a telescopic six-foot boom on top of the spacecraft and two magnetometers on seven-foot booms extended from the body, along with four solar panels. Weight, 136 pounds.

Project Objectives – Second in a series of seven Interplanetary Monitoring Platform (IMP) spacecraft planned to make measurements in the region between earth and moon and, on two later flights, in lunar orbit. Explorer XXI specifically intended to obtain magnetic fields, radiation and solar wind data in the transition region between the earth's magnetosphere and interplanetary space.

Spacecraft Payload – Experimental instrumentation included a rubidium vapor magnetometer and two fluxgate magnetometers to measure magnitude and direction of magnetic fields; low-energy charged particle detector; three particle telescopes (geiger counters) and an ion chamber to measure galactic and solar cosmic rays; and curved-plate electrostatic analyzer, grid device and thermal ion electron sensor to study the solar wind. Spacecraft communication and data handling system included digital data processor, PFM telemetry and 4-watt transmitter. Satellite spin stabilized, with 20 rpm design spin rate. Silver-cadmium batteries and 11,520 solar cells intended to provide 38 watts.

Project Results – Explorer XXI was launched on October 4, 1964, but failed to reach its planned apogee of 126,500 miles, going instead into an orbit of 120 to 59,400 miles at an inclination of 33.5°. Satellite provided good data but only from within the magnetosphere rather than out to the transition region.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, spacecraft prime contractor, experimenter; Universities of California-Berkeley and Chicago, M.I.T. and NASA Ames Research Center, experimenters; Douglas, Delta prime contractor.

EXPLORER XXII
(Beacon Explorer B)

Launch Vehicle – Scout, similar to Explorer XX, except X-258 solid motor (5800-pound-thrust) was used in Altair II fourth stage.

Spacecraft Description – Identical to Beacon Explorer A, unsuccessfully launched on March 19, 1964. Octagonal main body 18 inches across and 12 inches high, made of honeycomb nylon and fiberglass. Four solar panels, each 10 inches by 5.5 feet, extended from main structure, and two 5-foot antennas and two dipole antennas were mounted on the ends of opposite solar panels. Dipole antenna also mounted on top and bottom of body. Truncated pyramid atop body was covered with 360 one-inch fused silica reflectors. Weight, 116 pounds.

Project Objectives – Explorer XXII was the last of five satellites in the first phase of NASA's ionosphere research program, and the first of five payloads in a geodetic satellite program. Ionosphere experiment was to provide data on variations in the ionosphere's structure and to relate ionospheric behavior to solar radiation. Geodetic studies included laser and doppler shift tracking experiments.

Spacecraft Payload – Four CW transmitters provided ionosphere experiment signals on 20, 40, 41 and 360 mc, plus 162 and 324 mc transmissions for doppler shift measurements. Pulsed ruby laser mounted on a tracking telescope at Wallops Island was intended to illuminate the glass reflectors and the reflected light's travel time used to determine satellite slant range. Spacecraft systems included spin stabilization attitude control initially, with spin rate gradually reduced to zero by magnetic despin rods. Two bar magnets were mounted inside satellite's shell to passively orient the spacecraft along earth's magnetic field. Solar cells and nickel-cadmium batteries provided electrical power. Internal temperatures maintained above 70° by vacuum insulation between spacecraft electronics and external shell and by special bank of solar cells.

Project Results – Explorer XXII was launched from Vandenberg AFB on October 10, 1964 and successfully placed in an orbit ranging from 549 to 669 miles at 80° inclination. Magnetic stabilization was achieved within 48 hours. More than 90 simple, low-cost ground stations throughout the world are receiving the satellite's uncoded radio signals. Laser tracking was first accomplished October 11, although the returned signal has been weaker than expected.

Major Participants – NASA Goddard Space Flight Center, spacecraft management, experimenter; Applied Physics Laboratory, Johns Hopkins Univ., spacecraft prime contractor; Univ. of Illinois, Pennsylvania State University, Stanford Univ. and NBS Central Radio Propagation Laboratory, experimenters; NASA Langley Research Center, launch vehicle management; USAF Space Systems Division, launch operations; Ling-Temco-Vought, Scout prime contractor.

Key Spacecraft Personnel		Affiliation
PM	F.T. Martin	NASA-GSFC
PS	L.H. Brace	NASA-GSFC
SC	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
RF Beacon	PI	L.J. Blumle	NASA-GSFC
Langmuir Probe	PI	L.H. Brace	NASA-GSFC
	OI	N.W. Spencer	NASA-GSFC
Laser Reflector	PI	H.H. Plotkin	NASA-GSFC
US Navy Doppler	PI	R.J. Anderle	US Naval Surface Weapons Center

MARINER III

Launch Vehicle – Atlas-Agena D: 360,000-pound-thrust Atlas D first stage and 15,500-pound-thrust Agena D second stage (first NASA use of Agena D). Height, 104 feet.

Spacecraft Description – Octagonal magnesium main body, 50 inches across. High-gain dish mounted atop main structure along with low-gain antenna on top of aluminum tube. Four solar panels extended from top side of octagon, with solar pressure vanes, each seven square feet of aluminized mylar sheet, attached to end of each solar panel. Spacecraft 9.5 feet high and 22.6 feet across. Weight, 575 pounds.

Project Objectives – Perform two planetary experiments during Mars fly-by (aiming zone centered 8600 miles from surface) and six interplanetary experiments along spacecraft trajectory. Flight also intended to provide engineering experience in spacecraft operation during long-duration flight away from sun. Mission designed for a flight distance of 350 million miles to reach Mars (about 8½ months flight time) and communication distance of 150 million miles at planetary encounter.

Spacecraft Payload – Single camera to take up to 21 still photos during fly-by; playback for transmission in digital form to earth expected to take 8.3 hours per photo. Second planetary experiment, occultation studies of Martian atmospheric pressure, was to be based on spacecraft transmissions as it passed behind planet. Interplanetary experiments included solar plasma probe, ionization chamber and Geiger-Mueller tube, solid-state radiation detector and three Geiger-Mueller tubes, helium vector magnetometer, cosmic ray telescope and two cosmic dust detectors. Spacecraft attitude control system employed 12 nitrogen gas jets, three gyros, sun sensors and Canopus star tracker, plus the solar pressure vanes. Ten-watt transmitter intended to return all data except photos in real time. Hydrazine-fueled engine with 51 pounds of thrust carried for up to two midcourse corrections. Central computer and sequencer provided to control mission sequences. Combination of painted and polished surfaces, thermal shields, insulation and louvers employed for temperature control. Power supplied by 28.224 solar cells and silver-zinc batteries.

Project Results – Mariner III was successfully placed in parking orbit following launch from Cape Kennedy on November 5, 1964. Earth escape trajectory was achieved by second Agena burn but spacecraft did not reach planned speed of 25,661 mph and subsequently failed to extend its solar panels and to acquire the sun and Canopus. Project officials concluded that Mariner III's fiberglass shroud did not completely jettison as scheduled 5½ minutes after launch. Tests indicated shroud's inner layer separated under combined stresses of aerodynamic heating and rapid pressure drop at altitude. Transmissions ceased nine hours after launch; spacecraft was in solar orbit.

Major Participants – Jet Propulsion Laboratory, spacecraft management, spacecraft prime contractor, tracking; TRW Space Technology Laboratories, central computer and sequencer; Motorola, communication system components; NASA Lewis Research Center, launch vehicle management; USAF Space Systems Division, launch operations; General Dynamics/Astronautics, Atlas prime contractor; Lockheed, Agena prime contractor.

Key Spacecraft Personnel		Affiliation
PM	Jack N. James/ Dan Schneiderman	JPL
PS	Richard K. Sloan	JPL
MG	Glenn A. Reiff	

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	R.B. Leighton	California Institute of Technology
Magnetometer	PI	E.J. Smith	NASA-JPL
Faraday Cup	PI	H.S. Bridge	Massachusetts Institute of Technology
Cosmic Ray Telescope	PI	J.A. Simpson	University of Chicago
	OI	J.J. O'Gallagher	University of Maryland
Low Energy Cosmic Ray	PI	J.A. Van Allen	University of Iowa
	OI	S.M. Krimigis	Applied Physics Laboratories
Cosmic Ray Ionization	PI	V.H. Neher	California Institute of Technology
Cosmic Dust	PI	W.M. Alexander	Baylor University
Martian Atmosphere	PI	A.J. Kliore	NASA-JPL
	OI	D.L. Cain	NASA-JPL
	OI	F.D. Drake	Cornell University
	OI	V.R. Eshleman	Stanford University
	OI	G.S. Levy	NASA-JPL

EXPLORER XXIII
(S-55C)

Launch Vehicle – Scout, similar to Explorer XX, except 5800-pound-thrust Altair II fourth stage employed.

Spacecraft Description – Cylinder 24 inches in diameter and 92 inches long (payload experiments were mounted around the fourth stage casing). Weight, 295 pounds.

Project Objectives – Primary purpose to provide data on meteoroid penetration and the resistance of various materials to penetration. Secondary spacecraft objective was to flight test capacitor detectors to be carried by the large Pegasus meteoroid detection satellites and to obtain solar cell degradation information. In addition, the launch was scheduled so as to encounter winds of 70 mph or higher at 25,000 to 40,000 feet to provide data on Scout air loads. The satellite was a follow-on to Explorer XIII, orbited for only two days, and Explorer XVI, which supplied meteoroid data for seven months.

Spacecraft Payload – Four types of meteoroid experiments: 1) 216 pressurized stainless steel half-cylinder detectors of 0.001- and 0.002-inch wall thickness, 2) 24 triangular aluminum sounding board impact detectors, 3) two cadmium-sulphide cells mounted beneath aluminized mylar film, 4) two capacitor detectors of stainless steel, mylar and copper. Two groups of n-on-p solar cell samples carried, one unshielded and one with 3/16-inch quartz covering. Separate solar cells and nickel-cadmium batteries provided power for telemetry systems on 136.08 and 136.86 mc. Timing device carried to cut off transmissions after one year. Spacecraft spin stabilized.

Project Results – Explorer XXIII was launched from Wallops Island on November 6, 1964 and orbited from 288 to 610 miles at 52° inclination. All experiments were transmitting except the cadmium-sulphide cells, disabled during launch.

Major Participants – NASA Langley Research Center, spacecraft and launch vehicle management, spacecraft prime contractor, experimenter; NASA Goddard Space Flight Center, experimenter; Ling-Temco-Vought, Scout prime contractor.

Experiment	Experiment Personnel	Affiliation
Pressurized Cells	PI C.A. Gurtler	NASA-LARC
	OI G.W. Green	NASA-LARC
Impact Detectors	PI D.G. Holden	NASA-LARC
	OI A.G. Beswick	NASA-LARC
Cadmium Sulfide Cells	PI L. Secretan	NASA-LARC
Capacity Detectors	PI J.H. Siviter	NASA-LARC

EXPLORERS XXIV AND XXV (Air Density Explorer A and Injun 4)

Launch Vehicle – Scout, similar to Explorer XX, except fourth stage used X-258 solid motor.

Spacecraft Description – Explorer XXIV: Repeat of Explorers IX and XIX– an inflatable 12-foot balloon. Skin of four alternating layers of 0.005 inch aluminum foil and mylar, with outside layer aluminum to reflect sunlight and radio waves. Surface covered with 4000 white dots for passive thermal control. Weight, 19 pounds. Explorer XXV: Aluminum shell with 40 sides, 24 inches in diameter. Solar cells covered 30 sides. Cylindrical tube on top contained Explorer XXIV prior to ejection and inflation. Three short experiment booms extended from the spacecraft. Weight, 90 pounds.

Project Objectives – The two satellites were expected to provide detailed information on complex radiation-air density relationships in the upper atmosphere. Explorer XXIV designed to measure atmospheric density at same time Explorer XXV was obtaining particle flux and energy data in same general area. Planned near-polar orbit had a perigee point timed to initially arrive in the North Polar region about the time of the Winter solstice and to move around the earth about once every six months. Satellites were part of the U.S. IQSY effort.

Spacecraft Payload – Explorer XXIV: Only equipment was a tracking transmitter inside satellite, powered by 280 solar cells and nickel-cadmium batteries. Sphere was separated into halves by a mylar insulating gap and was intended to serve as its own antenna. Explorer XXV: Carried 16 radiation sensors, including 5 omnidirectional detectors (three Geiger-Mueller tubes and two boom-mounted spherical retarding potential analyzers) and 11 directional detectors (four Geiger-Mueller tubes, two scintillation counters and five cadmium-sulphide sensors). Two AFCRL low-energy particle detectors were also included in the payload. Satellite designed to be aligned with earth's magnetic field by a permanent magnet. Magnetic despin rod carried to stop spacecraft spinning or tumbling, and boom-mounted magnetometer and internal electromagnet employed to maintain alignment. Spacecraft included a command receiver, tape recorder and two telemetry transmitters on 136.29 and 136.86 mc. Power supplied by 2640 solar cells and nickel-cadmium batteries.

Project Results – NASA's first dual payload was launched from Vandenberg AFB on November 21, 1964 and Explorer XXV injected into an orbit of 345 to 1547 miles at 81° inclination. Explorer XXIV was then inflated and ejected into a nearby orbit of 344 to 1551 miles at 81° inclination. Maximum north latitude reached by perigee occurred about December 27, 1964. All experiments were performing as designed.

Major Participants – NASA Langley Research Center, spacecraft and launch vehicle management, Explorer XXIV prime contractor and experimenter; Univ. of Iowa, Explorer XXV prime contractor and experimenter; USAF Cambridge Research Laboratories, Explorer XXV experimenter; Bendix, Explorer XXV structure and power supply; USAF Space Systems Division, launch operations; Ling-Temco-Vought, Scout prime contractor.

Key Spacecraft Personnel		Affiliation
Air Density Explorer		
PM	C.W. Coffee, Jr.	NASA-LARC
PS	R.F. Fellows	NASA Headquarters
CO	G.M. Keating	NASA-LARC
Injun 4		
PM	J. Van Allen	University of Iowa
PS	J.A. Van Allen	University of Iowa

Experiment	Experiment Personnel		Affiliation
Air Density Explorer, Nonsystematic Changes Air Density	PI	L.G. Jacchia	SAO
Air Density Explorer, Systematic Changes Air Density	PI	W.J. O'Sullivan, Jr.	NASA-LARC
	OI	C.W. Coffee, Jr.	NASA-LARC
	OI	G.M. Keating	NASA-LARC
Injun 4, SEE64-0768	PI	J.A. Van Allen	University of Iowa
Injun 4, Retarding Potential Analyzer	PI	R.C. Sagalyn	USAF
Injun 4, GM Detectors (7)	PI	J.A. Van Allen	University of Iowa
Injun 4, P-N Junction Detector	PI	J.A. Van Allen	University of Iowa
	OI	S.M. Krimigis	Applied Physics Laboratory
Injun 4, CDS Detector	PI	J.A. Van Allen	University of Iowa
Injun 4, Plastic Scintillators	PI	J.A. Van Allen	University of Iowa
	OI	J.D. Craven	University of Iowa

MARINER IV

Launch Vehicle – Atlas-Agena D, same as Mariner III, except magnesium shroud replaced fiberglass version that failed during Mariner III launch.

Spacecraft Description – Same as Mariner III.

Project Objectives – Second of two 1964 Mars flyby launches. Mission objectives identical to Mariner III.

Spacecraft Payload – Same as Mariner III.

Project Results – Mariner IV was successfully launched from Cape Kennedy on November 28, 1964 and injected into a Mars trajectory with a miss distance of 151,000 miles. Spacecraft acquired Canopus on November 30, after first locking on several wrong stars. Midcourse maneuver successfully carried out December 5, with engine fired for 20.06 seconds and trajectory altered so that Mariner IV will pass behind Mars and within 5400 miles of planet. A second correction was not required. Solar plasma experiment malfunctioned December 7. The same day, Canopus lock was again lost but was reacquired December 17. Programmed switch from cavity amplifier to TWT amplifier December 13 increased spacecraft's transmitter power level, and telemetry rate was reduced to 8-1/3 bits per second January 3, 1965. On January 10 the spacecraft was traveling 8624 mph relative to earth and 70,099 mph relative to the sun, and had traveled a total of 74.5 million miles (7.5 million miles relative to earth). Travel distance to Mars was 325 million miles; the planet was 134 million miles from earth during Mariner IV's flyby.

Major Participants – Jet Propulsion Laboratory, spacecraft management, spacecraft prime contractor, tracking; TRW Space Technology Laboratories, central computer and sequencer; Motorola, communication system components; NASA Lewis Research Center, launch vehicle management; USAF Space Systems Division, launch operations; General Dynamics/ Astronautics, Atlas prime contractor; Lockheed, Agena prime contractor.

Key Spacecraft Personnel		Affiliation
PM	Jack N. James/ Dan Schneiderman	JPL
PS	Richard K. Sloan	JPL
MG	Glenn A. Reiff	

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	R.B. Leighton	California Institute of Technology
Magnetometer	PI	F.J. Smith	NASA-JPL
Faraday Cup	PI	H.S. Bridge	Massachusetts Institute of Technology
Cosmic Ray Telescope	PI	J.A. Simpson	University of Chicago
	OI	J.J. O' Gallagher	University of Maryland
	CO	G. Lentz	University of Chicago
GM Detector (C.R. Proton, Electron)	PI	J.A. Van Allen	University of Iowa
	OI	L.A. Frank	University of Iowa
	OI	S.M. Krimigis	Applied Physics Laboratory
	CO	H. Kiel	University of Iowa
Cosmic Ray Ionization	PI	V.H. Neher	California Institute of Technology
	CO	H.R. Anderson	Rice University
Cosmic Dust	PI	W.M. Alexander	Baylor University
Occultation S-Band	PI	A.J. Kliore	NASA-JPL
Celestial Mechanics	PI	J.D. Anderson	NASA-JPL
	OI	G.W. Null	NASA-JPL
Radio Propellant	PI	R.M. Goldstein	NASA-JPL
Micrometeorites	PI	J.L. Bohn	Temple University
	OI	W.M. Alexander	Baylor University
	OI	B.V. Connor	NASA-JPL
Cosmic Ray Telescope	PI	J.A. Simpson	University of Chicago
	OI	J.J. O' Gallagher	University of Maryland
Interplanetary Plasma	PI	H.S. Bridge	Massachusetts Institute of Technology
	OI	A.J. Lazarus	Massachusetts Institute of Technology
	OI	C.W. Snyder	NASA-JPL
Solar Cosmic Rays	PI	J.A. Van Allen	University of Iowa
	OI	L.A. Frank	University of Iowa
	OI	S.M. Krimigis	Applied Physics Laboratory

SAN MARCO I

Launch Vehicle – Four-stage solid propellant Scout, same as Explorer XX, except 5800-pound-thrust four stage used.

Spacecraft Description – Heavy spherical structure contained within lightweight aluminum spherical outer shell; 26 inches in diameter. Weight, 254 pounds.

Project Objectives – Orbital flight test of satellite prior to launch into equatorial orbit in late 1965 or 1966 from anchored platform in Indian Ocean near equator. Spacecraft intended to furnish data on air density and ionosphere characteristics.

Spacecraft Payload – Air density experiment designed to measure atmospheric drag at perigee on satellite's light outer shell; drag gauged by three orthogonal displacement transducers connecting inner and outer spheres. Transducer data returned by 2-watt transmitter on 136.53 mc. Ionosphere experiments based on signals from ½-watt transmitter on 20.005 mc. Spacecraft spin stabilized and powered by mercury batteries.

Project Results – San Marco I was launched from Wallops Island by an Italian crew on December 15, 1964. Satellite placed in an orbit of 128 to 510 miles, somewhat more elliptical than planned, at 38° inclination.

Major Participants – Italian Space Commission, spacecraft management; Univ. of Rome Aerospace Research Center, spacecraft prime contractor, launch operations; NASA Langley Research Center, launch vehicle management; NASA Goddard Space Flight Center, tracking and data acquisition; Ling-Temco-Vought, Scout prime contractor.

Key Spacecraft Personnel		Affiliation
PM	A.J. Caporale	NASA-GSFC

Experiment	Experiment Personnel	Affiliation
Atmosphere	PI L. Broglio	National Research Council of Italy
RF Beacon	PI N. Carrara	University of Florence

EXPLORER XXVI (Energetic Particles Explorer D)

Launch Vehicle – Delta, similar to Explorer XXI.

Spacecraft Description – Octagonal platform atop a truncated cone, 27-3/4 inches across and 17 inches high. Four solar panels extended from the sides and 34-inch tube supporting a magnetometer was mounted on top of the spacecraft. Weight, 101 pounds.

Project Objectives – Principal purpose was to provide data on high-energy particles – how they are injected, trapped and eventually lost in the Van Allen radiation belts. Satellite's five experiments were identical to those carried by Explorer XV.

Spacecraft Payload – Experiment instrumentation included solid-stage detectors to measure spatial and angular distribution and energy spectra of electrons and protons, scintillation detectors to provide data on intensity and angular distribution of protons and electrons, fluxgate magnetometer to measure magnetic field magnitude and direction from 6000 miles out to apogee, scintillation detector for data on low-energy particles and solar cell damage experiment with four groups of n-on-p cells with various shielding. Spacecraft spin stabilized, 25 rpm design spin rate. PCM telemetry; 2-watt transmitter on 136.275 mc. Power supply included 6144 p-on-n solar cells and silver-cadmium batteries.

Project Results – Explorer XXVI was launched from Cape Kennedy on December 21, 1964 and placed in an orbit of 190 to 16,280 miles at 20° inclination.

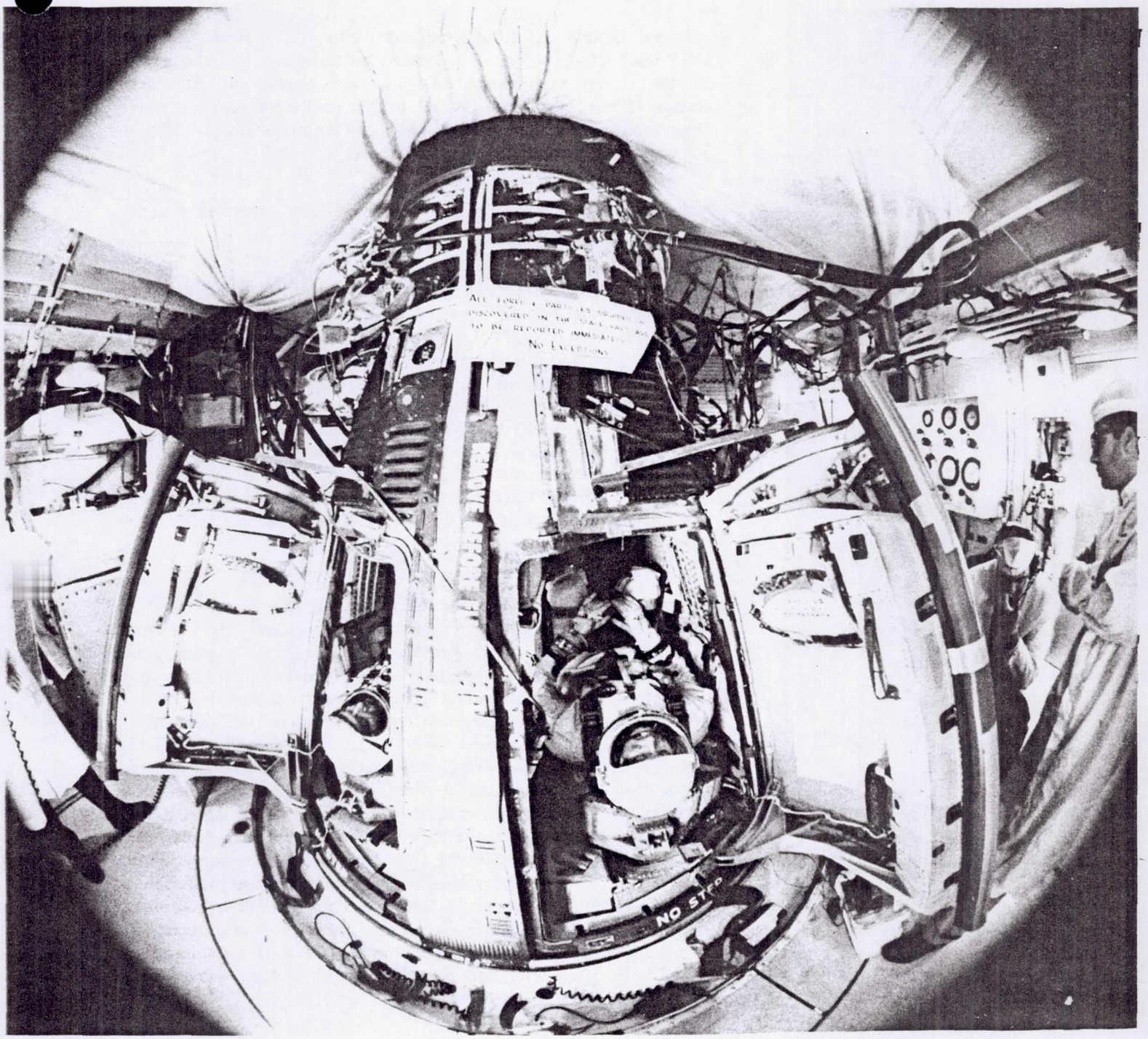
Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, spacecraft prime contractor, experimenter; Bell Telephone Laboratories, Univ. of California-San Diego and Univ. of New Hampshire, experimenters; Douglas, Delta prime contractor.

Key Spacecraft Personnel		Affiliation
PM	G.W. Longanecker	NASA-GSFC
PS	L.R. Davis	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Charged Particle Detector	PI	W.L. Brown	Bell Telephone Laboratories
	OI	L.J. Lanzerotti	Bell Telephone Laboratories
	OI	L. Medford	Bell Telephone Laboratories

Experiment	Experiment Personnel	Affiliation
Electron Proton	PI C.E. McIlwain	University of California, San Diego
	OI R.W. Fillius	University of California, San Diego
Magnetic Field	PI L.J. Cahill, Jr.	University of Minnesota
0.1-10MeV Proton + Electron Scintillator	PI L.R. Davis	NASA-GSFC
	OI J.M. Williamson	NASA-GSFC
Solar Cell Damage	PI L.W. Slifer, Jr.	NASA-GSFC

1965



Gemini VI simulated flight test with astronauts Walter H. Schirra, Jr., command pilot (left), and Thomas P. Stafford, pilot (right). This test prepared astronauts for the rendezvous of Gemini VI with Gemini VII.

TIROS IX

Launch Vehicle – Delta, same as Explorer XXVIII.

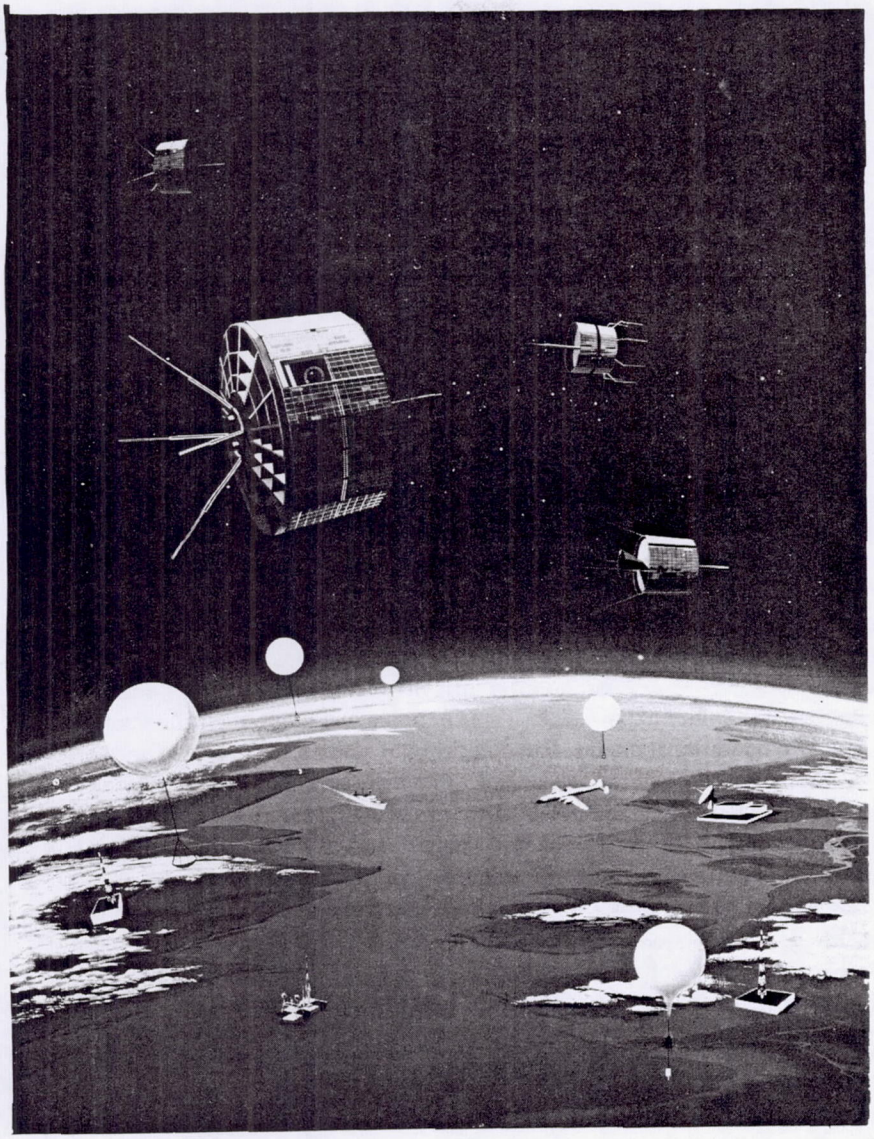
Spacecraft Description – Configuration similar to previous Tiros satellites– an 18-sided polygon, 42 inches in diameter and 22 inches high. The two television cameras were mounted on opposite sides of spacecraft. Solar cells covered sides and top. An 18-inch receiving antenna mounted on top and four transmitting whip antennas extended from bottom of Tiros IX. Weight, 305 pounds, heaviest satellite yet in Tiros series.

Project Objectives – Primary purpose was to test Tiros "cartwheel" configuration for Weather Bureau's Operational TOS system.

Spacecraft Payload – Television system included two ½-inch, 500 scan line wide-angle vidicon cameras, canted 26.5° on opposite sides of satellite's rotational plane to provide adequate width coverage for full global observation. Under normal operation each camera would take 16 pictures per orbit at 128-second intervals, with capability to decrease interval to 64 or 32 seconds. Each camera had two independent triggering systems. Two tape recorders capable of storing up to 48 pictures each used when satellite was out of range of ground stations in Alaska, California and Virginia. Magnetic coil, small solid propellant rockets and despin weights used to maintain 10 rpm spin rate and magnetic coil also employed, with two infrared horizon sensors, for attitude control. Power supplied by 9100 n-on-p solar cells and nickel-cadmium batteries.

Project Results – Tiros IX was launched from Cape Kennedy on January 22, 1965 in the first attempt to reach polar orbit from the Cape. Series of three Delta dog-leg maneuvers – right yaws during first and second stage ignitions and pitch down and left yaw prior to third stage ignition – placed spacecraft in its planned sun-synchronous 82° retrograde orbit. Second stage burn failed to cut off on schedule, however, resulting in 435 to 1602 mile orbit rather than planned 400 mile circular orbit. Satellite spin axis initially in orbital plane, then rotated by magnetic torquing coil into alignment perpendicular to orbital plane and tangent to earth's surface – the key element in cartwheel configuration. This maneuver accomplished during first 20 orbits. Higher apogee permitted spacecraft to cover more of earth than planned, with pictures of excellent quality. First photomosaic of entire world's cloud cover provided by 450 pictures taken by Tiros IX on February 13. Ground commands modified satellite's attitude to maintain proper solar relationship, and 180° turn-around maneuver conducted in April to prevent spacecraft overheating and ensure continued solar power. One camera malfunctioned April 9, but another camera continued to provide about 250 pictures daily.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; Weather Bureau, data analysis and distribution; Douglas, launch vehicle prime contractor.



Artist's early concept of space and terrestrial weather observation facilities. Pictured in the foreground is Tiros IX.

Key Spacecraft Personnel		Affiliation
PM	R.M. Rados	NASA-GSFC
PS	Aerospace and Meteorology Division	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	Ness Staff	NOAA-NESS

OSO II

Launch Vehicle – Delta, same as Explorer XXVIII.

Spacecraft Description – Composed of two sections: spinning nine-sided base or "wheel" section and stabilized fan-shaped "sail" section. Wheel section 44 inches across and 9 inches high; fiberglass balls on ends of three arms extended from wheel to give it overall diameter of 92 inches. Sail section nearly a semicircle with 22-inch radius; one side faced with solar cells with pointing-scanning experiment package mounted on that face. Total spacecraft height, 37 inches. Weight, 545 pounds.

Project Objectives – Second in series of eight OSO spacecraft intended to measure frequency and energy of solar electromagnetic radiation in ultraviolet, X-ray and gamma ray regions of spectrum.

Spacecraft Payload – OSO II originally was scheduled to be launched in April 1964. Accidental third stage ignition during preflight checkout, however, killed three technicians and severely damaged the spacecraft. Parts salvaged from original OSO and components from a prototype used to rebuild OSO II. Eight experiments totaling 215 pounds carried. Five experiments located in wheel section: zodiacal light device, high and low energy gamma ray experiments, astronomical ultraviolet spectrophotometer and emissivity stability experiment. Three experiments mounted on sail section had two operational modes, fine pointing and raster scan: ultraviolet spectrometer, solar X-ray telescopes and white light coronograph, and ultraviolet telescopes. Wheel section designed to spin at 30 rpm; rate maintained by nitrogen jets, with gas stored in 6-inch fiberglass balls. Sail designed to maintain pointing accuracy of 1 minute of arc during daylight. Coarse elevation control provided by gas jets; fine elevation and azimuth pointing provided by electrical servomotors. OSO II included new PCM telemetry system, new command system capable of receiving 70 commands and improved tape recorder. Thirty watts of power supplied by 1860 solar cells and batteries.

Project Results – OSO II was launched from Cape Kennedy on February 3, 1965 and injected into orbit of 343 to 393 miles at 33° inclination. Pointing instruments oriented with initial error of about 0.5 arc minute; drift less than 10 arc seconds in first six months of operation. All but one experiment, the ultraviolet spectrometer, worked initially and have achieved their scientific objectives. High voltages and other problems have now disabled three other experiments; OSO II's experiments have been affected by South Atlantic magnetic anomaly, and have provided useful data on anomaly location, intensity and structure.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, experimenter; Ball Brothers Research Corp., spacecraft prime contractor; Harvard Univ., Naval Research Laboratory, NASA Ames Research Center and Universities of Minnesota and New Mexico, experimenters; Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	J.C. Lindsay	NASA-GSFC
SC	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
Ultraviolet Experiment Failed on Launch	PI	L. Goldberg	Harvard College Observatory
Solar X-Ray Burst	PI	T.A. Chubb	US Naval Research Laboratory
Corona, White Light	PI	R. Tousey	US Naval Research Laboratory
Zodiacal Light Monitor	PI	E. Ney	Unknown
	CO	G. Burnette	University of Minnesota
Cosmic Gamma Ray 100-1000 MeV	PI	C.P. Leavitt	University of New Mexico
Gamma Ray	PI	K.J. Frost	NASA-GSFC
UV Spectrometer	PI	K.L. Hallam	NASA-GSFC
Emissivity	PI	C.B. Neel, Jr.	NASA-ARC
Solar UV Photom. Scan.	PI	R. Tousey	US Naval Research Laboratory
	OI	J.D. Purcell	US Naval Research Laboratory

This tracking station near Quito, Equador, was one of some 18 tracking stations located around the globe which could receive, record, and relay vital data from unmanned spacecraft orbiting the Earth. The station was part of NASA's satellite tracking and data acquisition network (STADAN). The number of stations varied according to mission requirements.



PEGASUS I

Launch Vehicle – Saturn I (SA-9): 1,504,000-pound-thrust S-I first stage, 90,000-pound-thrust S-IV second stage and redesigned instrument unit with inertial guidance system. Boilerplate Apollo command and service modules and launch escape system mounted atop vehicle. Height, 188 feet.

Spacecraft Description – In orbital configuration Pegasus I consisted of two large "wings," each 14 x 48 feet, and four solar panels extended from open-truss rectangular aluminum center structure mounted on top of second stage. Total weight, about 23,000 pounds.

Project Objectives – To obtain scientific and engineering design data on magnitude and direction of intermediate size meteoroids in near-earth orbit and to provide experience with new meteoroid penetration detection system.

Spacecraft Payload – At launch spacecraft's experiment portion, which weighed about 3126 pounds, was stored within boilerplate Apollo service module. Each wing consisted of seven hinged frames, spring loaded to unfold from center section in accordion fashion with deployment rate controlled by scissor-like links driven by electric motor. Use of both sides of 208 panels, each 20 x 40 inches, provided more than 2300 square feet of flat plate capacitor detection surface. Each panel composed of polyurethane foam core with aluminum-mylar-copper laminated skin. Three aluminum thicknesses, to measure three levels of impact energy, used in these capacitor sheets: 0.0015-inch on 16 panels, 0.008-inch on 32 panels and 0.016-inch on 368 panels. Detection system designed so that a micrometeoroid penetration would temporarily discharge capacitor sheet and resulting pulse stored in spacecraft's memory system, then relayed to ground upon command. Solar and earth aspect sensors provided directional data. Power supplied by 25,000 n-on-p solar cells and nickel-cadmium batteries. Spacecraft electronics located in cannister temperature.

Project Results – Pegasus I launched from Cape Kennedy on February 16, 1965, was placed in orbit of 308 to 463 miles at 32° inclination. Apollo boilerplate modules were separated and fourteen minutes after launch 40-second wing deployment sequence initiated. Successful deployment confirmed in real time by television camera mounted on second stage. Useful results have been obtained from 1.5 mil panels (54 hits recorded by late May), but data from other two thicknesses have not been fully satisfactory. Because logic networks link capacitor circuitry, short circuits in some capacitors have required all 8 mil and most 16 mil panels to be disconnected. Pegasus I continues to provide some data.

Major Participants – NASA Marshall Space Flight Center, spacecraft and launch vehicle management; Fairchild Hiller, spacecraft prime contractor; Adcole Corp., solar aspect sensor; G. T. Schjeldahl Corp., detector panels; TRW Systems, electron spectrometer; Chrysler, first stage prime contractor; Douglas, second stage prime contractor.

Key Spacecraft Personnel		Affiliation
PM	L.C. Garvin	NASA-MSFC
PA	J.B. Dozier, Jr.	NASA-MSFC
MG	C.D. Ashworth	NASA-MSFC

Experiment	Experiment Personnel		Affiliation
Meteoroid Detectors	PI	R.J. Naumann	NASA-MSFC
	OI	K.S. Clifton	NASA-MSFC
Electron Spectrometer	PI	R.A. Potter	NASA-MSFC
Thermal Surface Coating	PI	Unknown	Unknown

RANGER VIII

Launch Vehicle – Atlas-Agena B: 370,000-pound-thrust Atlas D first stage and 16,000-pound-thrust Agena B second stage programmed for two burns. Atlas used radio guidance, Agena inertially guided. Height, 104 feet.

Spacecraft Description – Same as Rangers VI and VII – a 380-pound conical camera structure mounted on hexagonal spacecraft bus. Payload covered by polished aluminum shroud with 13-inch opening near top for television cameras. Omnidirectional antenna mounted on top of camera structure. Bus constructed of aluminum and magnesium tubing and structural members. Electronic packages attached to each side and midcourse motor set inside structure with nozzle pointed down. High-gain antenna and two solar panels hinged to spacecraft's base. Fully deployed, Ranger VIII was 15 feet across solar panels and 10¼ feet high. Weight, 809 pounds.

Project Objectives – To provide additional scientific information on the moon's surface as well as lunar topographical data in support of Surveyor and Apollo programs.

Spacecraft Payload – Television system employed two wide-angle F cameras, four narrow-angle P cameras, camera sequencer, video combiner, two 60-watt transmitters, telemetry system and two silver-zinc batteries. Principal change from Rangers VI and VII was increased sensitivity of the three cameras (one wide- and two narrow-angle) with f/2 apertures to compensate for lower light levels closer to moon's terminator. Spacecraft systems included 3-watt receiver-transmitter for ground commands and telemetry. Attitude control maintained by redundant nitrogen gas systems of six jets each, four primary and two secondary sun sensors, earth sensor and three gyros; all events programmed by digital central computer and sequencer. Midcourse motor, fueled with monopropellant hydrazine, provided 50 pounds of thrust for up to 98.5 seconds. Power supply of 200 watts furnished by 4896 solar cells and silver-zinc batteries.

Project Results – Ranger VIII was launched from Cape Kennedy on February 17, 1965 and placed in parking orbit, then injected into lunar trajectory. Telemetry signal strength decreased unexpectedly during pitch turn prior to midcourse maneuver, but returned to normal when engine was successfully fired. Terminal maneuver omitted as Ranger VIII made a relatively shallow approach (49° off vertical), providing photography of 900,000 square mile conical area before impact in Sea of Tranquility at 2.59°N and 24.77°E, within 15 miles of its target. Flight time was 64.54 hours; flight distance was 248,766 miles. Total of 7137 high quality photographs returned with best resolution "only" about 5 feet due to shallow approach.

Major Participants – Jet Propulsion Laboratory, project management, spacecraft prime contractor and Deep Space Network; RCA, television system; Northrop, central computer and sequencer, attitude control subsystems; NASA Lewis Research Center, launch vehicle management; General Dynamics/Convair, first stage prime contractor; Lockheed, second stage prime contractor; TRW Systems, launch vehicle guidance equations.

Key Spacecraft Personnel		Affiliation
PM	Harris M. Schurmeier	JPL
PS	None	
MG	N. William Cunningham	
PI	G.P. Kuiper	University of Arizona
OI	R.L. Heacock	NASA-JPL
OI	E.A. Whitaker	University of Arizona
OI	R.J. Naumann	NASA-MSFC
OI	E.M. Shoemaker	California Institute of Technology
OI	H.C. Urey	University of California, San Diego

RANGER IX

Launch Vehicle – Atlas-Agena B, same as Ranger VIII.

Spacecraft Description – Same as Ranger VIII. Weight, 809 pounds.

Project Objectives – Last spacecraft in nine-vehicle Ranger program. Crater Alphonsus selected as primary impact area.

Spacecraft Payload – Same as Ranger VIII.

Project Results – Ranger IX, launched from Cape Kennedy on March 21, 1965, was successfully injected from parking orbit into lunar trajectory. Midcourse maneuver moved spacecraft's aiming point 322 miles south to spot within crater Alphonsus. Terminal maneuver employed for first time in Ranger program to align cameras with descent path. Initial photographs received from altitude of 1405 miles above lunar surface and last photos from altitude of 0.38 mile. Ranger IX returned 5814 pictures of excellent quality, covering area of 600,000 square miles. Impact was within 2.76 miles of target point, at 12.91°S and 2.38°W. Flight time, 64.52 hours; flight distance, 259,143 miles. Features down to 10 inches across photographed. Almost 200 pictures were relayed live via commercial television, providing spectacular bonus to Ranger program's finale.

Major Participants – Jet Propulsion Laboratory, project management, spacecraft prime contractor and Deep Space Network; RCA, television system; Northrop, central computer and sequencer, attitude control subsystems; NASA Lewis Research Center, launch vehicle management; General Dynamics/Convair, first stage prime contractor; Lockheed, second stage prime contractor; TRW Systems, launch vehicle guidance equations.

Key Spacecraft Personnel		Affiliation
PM	Harris M. Schurmeier	JPL
PS	None	
MG	N. William Cunningham	
PI	G.P. Kuiper	University of Arizona
OI	R.L. Heacock	NASA-JPL
OI	E.M. Shoemaker	California Institute of Technology
OI	H.C. Urey	University of California, San Diego
OI	E.A. Whitaker	University of Arizona

GEMINI III

Launch Vehicle – Modified Titan II: 430,000-pound-thrust first stage, 100,000-pound-thrust second stage; storable, hypergolic liquid fuels; radio guidance system. Height, 108 feet.

Spacecraft Description – Conical vehicle composed of two components; re-entry module with cabin, re-entry control, and rendezvous and recovery sections, and adapter module with retrograde and equipment sections. Principal re-entry module structural material was titanium, with nickel alloy and beryllium used for shingles. Adapter module constructed mainly of magnesium. Re-entry module 39 inches in diameter at top, 90 inches at base; adapter module 90 inches in diameter at top, 10 feet at base. Total height, 18.4 feet. Weight, 7110 pounds.

Project Objectives – First manned Gemini flight, orbit for three passes, and recover spacecraft and two-man crew; demonstrate and evaluate launch vehicle, spacecraft (including maneuver capability) and tracking systems. Secondary objectives included general photographic coverage, re-entry communication test and experiments on effects of zero gravity and radiation on human white blood cells.

Spacecraft Payload – Crew of command pilot Virgil I. "Gus" Grissom, 38, and pilot John W. Young, 34. Spacecraft systems included environmental control system, with 100 percent oxygen environment at 5.0 psi. Orbit attitude and maneuver system used 16 jets with thrusts of 25, 85 and 100 pounds for extensive translation maneuvers along three axes. Re-entry control system, with 16 thrusters, used for manual control of spacecraft attitude during firing of four solid propellant retrorockets and through re-entry. Two meals of four items each, two rehydrated with special water gun and two bite-sized, carried.

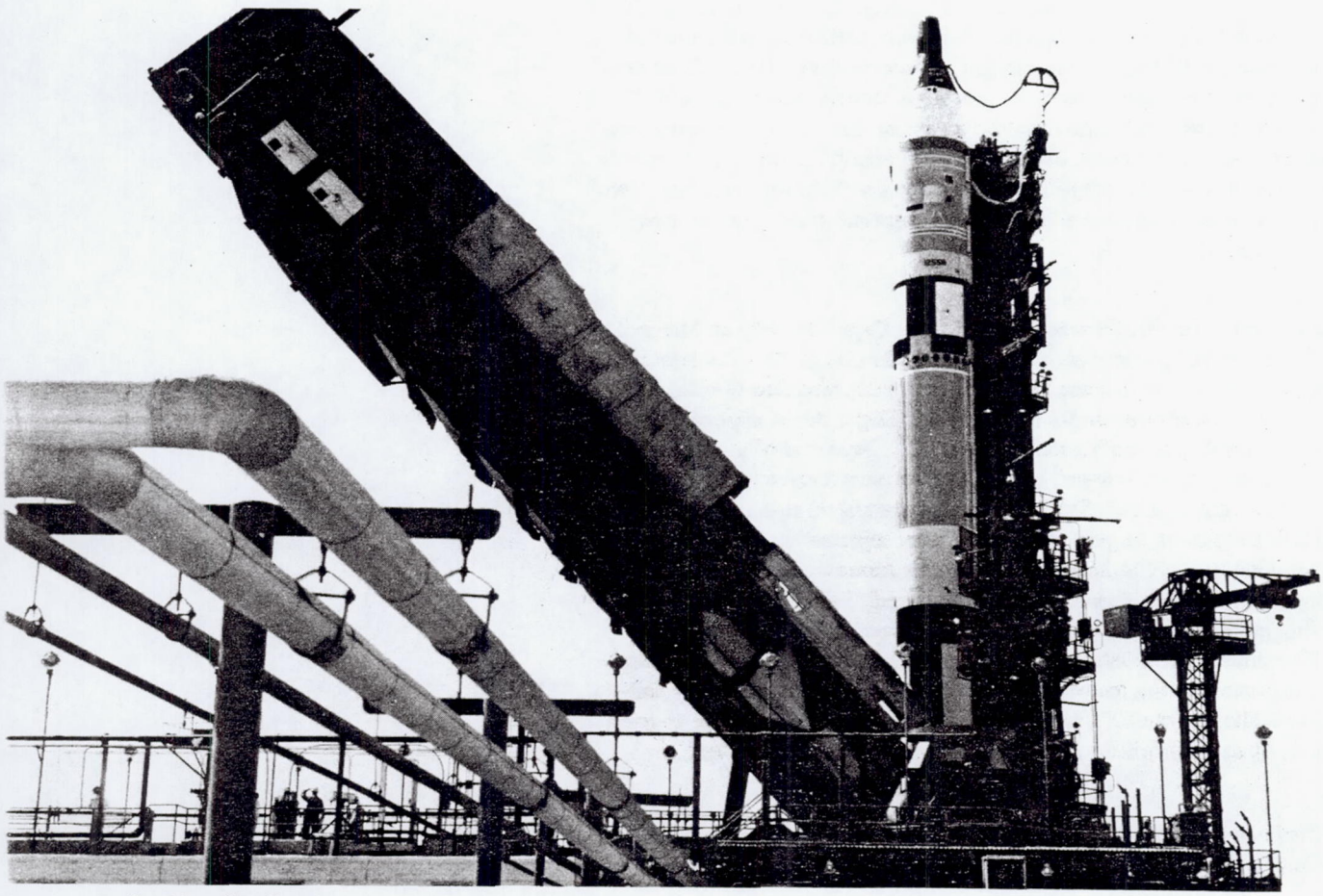
Project Results – Gemini III was launched from Cape Kennedy on March 23, 1965. Initial orbital parameters were 100 to 150 miles at 32.5° inclination. First manned maneuver in space, at end of first pass, modified Gemini III's orbit to near-circular orbit of 98 to 105 miles. Slight thrust applied on second orbit changed spacecraft's inclination 0.02°. Near end of third orbit Gemini III's perigee was lowered to 52 miles, to permit re-entry by natural decay if retrorockets failed. During manually controlled re-entry, at altitude of 300,000 feet, about 16 pounds of water were injected into ionized plasma sheath – which resulted in improved communications during blackout period. Impact in recovery area of Grand Turk Island, 59 miles short of nominal landing point due to less-than-expected spacecraft lift, occurred after 4 hours, 53 minutes. Both astronauts became seasick, removed their suits and left the spacecraft during recovery sequence. They were picked up by helicopters and taken to the USS Intrepid, where they were found to be in good condition. Spacecraft mission performance was considered excellent.

Major Participants – NASA Manned Spacecraft Center, project management; NASA Goddard Space Flight Center, space tracking and data acquisition;

McDonnell, spacecraft prime contractor; IBM and Honeywell, inertial guidance system; Rocketdyne, attitude and re-entry control systems; Garrett Corp., environmental control system; Collins Radio, communication system; Electro-Mechanical Research, telemetry system; Thiokol, retrorockets; Northrop Ventura, parachute recovery system; USAF Space Systems Division, launch vehicle management; Martin, launch vehicle integration; U.S. Navy, recovery task force management.

Experiment	Experiment Personnel	Affiliation
Sea Urchin Egg Growth	PI Unknown	Unknown
Re-Entry Communications	PI D.J. Schroeder	Beloit University
Synoptic Terrain Photos	PI P.D. Lowman, Jr.	NASA-GSFC
Eff. on Blood Cells	PI M.A. Bender	Holifield National Laboratory

Preparing for Gemini III, the first manned Gemini flight, with astronauts Virgil I. Grissom and John Young. The mission, successfully launched, lasted 3 hour, 53 minutes.



INTELSAT IF-I (Early Bird)

Launch Vehicle – Thrust-Augmented Delta (TAD): First stage Thor augmented by three TX-33-52 solid propellant motors for total thrust of 333,500 pounds, second stage a 7500-pound-thrust liquid engine and third stage a solid propellant X-258 motor rated at 5700-pound-thrust. First and second stages radio guided, third stage spin stabilized. Height, 90 feet.

Spacecraft Description – Cylinder 28 inches in diameter and 23 inches high. Aluminum and magnesium structure covered with solar cells. Apogee motor and four whip antennas extended from one end, 17-inch co-linear slot communications antenna from opposite end. Weight in orbit, 85 pounds.

Project Objectives – To provide commercial trans-Atlantic communications. Also, Early Bird was to afford Comsat Corp. its first operational experience, plus the opportunity to evaluate commercial capability of synchronous communication satellites.

Spacecraft Payload – Early Bird's redundant, frequency-translation, active-repeater communications system provided 240 two-way voice channels or a single television channel. Signals received at 6390 mc (from U.S.) and 6301 mc (from Europe) and re-transmitted at 4081 mc (to U.S.) and 4161 (to Europe). Redundant TWT transmitters had 6-watt outputs. Transmitting antenna gain, 9 db. Forty-five watts of power supplied by 6000 n-on-p solar cells, backed up by nickel-cadmium batteries. Solid propellant apogee kick motor designed to inject satellite into circular orbit. Dual hydrogen peroxide gas jet systems employed for initial positioning in synchronous, equatorial orbit and for attitude and velocity control. Early Bird utilized passive thermal control.

Project Results – Early Bird was launched from Cape Kennedy on April 6, 1965 into elliptical orbit. Apogee motor fired on sixth orbit to change orbit to circular at altitude of about 22,300 miles. Gas jet system then pulsed to slow satellite so that it drifted west to 27.5°W longitude over Atlantic Ocean. It reached that point April 15, and has since been maintained with minimum station-keeping at inclination of about 0.1°. First public TV demonstration held May 2. Following extensive demonstrations of Early Bird's capability for voice, data, facsimile, telegraphy and television transmission, commercial service was inaugurated June 28.

Major Participants – Communications Satellite Corporation, spacecraft management; Hughes, spacecraft prime contractor; NASA Goddard Space Flight Center, launch vehicle management, launch and tracking services; Douglas, launch vehicle prime contractor.

EXPLORER XXVII
(Beacon Explorer C)

Launch Vehicle – Scout, with four solid propellant stages: 1) Algol IIB, 105,000-pound-thrust, 2) Castor, 62,000-pound-thrust, 3) Antares, 22,000-pound-thrust, 4) Altair, 5700-pound-thrust (X-258 motor). First three stages inertially guided, fourth stage spin stabilized. Height, 72 feet.

Spacecraft Description – Similar to Beacon Explorer A, which failed to orbit, and Explorer XXII (Beacon Explorer B). Octagonal body of honeycomb nylon and fiberglass, 48 inches across and 12 inches high. Four blade-like solar panels, each 10 inches by 5.5 feet, extended from main structure. Two 5-foot antennas and two dipole antennas were mounted on ends of opposite solar panels. A dipole also extended from top and bottom of spacecraft. Array of 360 fused silica reflectors covered truncated pyramid mounted atop body. Weight, 132 pounds.

Project Objectives – First NASA satellite with gravimetric geodesy as its primary mission. Other objectives included global survey by 86 ground stations in 36 countries of electron content of cross-sections of the ionosphere, measurement of electron density and temperature in vicinity of spacecraft and laser tracking experiments.

Spacecraft Payload – Two coherent unmodulated CW transmitters on 162 and 324 mc provided transmissions for doppler shift geodetic measurement. Four similar transmitters on 20, 40, 41 and 360 mc used in ionosphere study. Electrostatic probe furnished data for electron density and temperature experiment. Pulsed ruby lasers used to illuminate glass reflectors; Explorer XXVII carried a photo-sensitive signal detector to confirm beam hits. Spacecraft systems included magnetic despin rods to reduce initial spin to zero and two bar magnets mounted inside satellite's shell to passively orient spacecraft along earth's magnetic field. Solar cells and nickel-cadmium batteries provided required 10 watts of power. Thermal control maintained by vacuum insulation and special bank of solar cells.

Project Results – Explorer XXVII was launched from Wallops Island on April 29, 1965 and placed in orbit of 584 to 819 miles at 41° inclination. All six transmitters were working as planned. The spacecraft was tracked by lasers at several locations, and the reflected light photographed as well.

Major Participants – **NASA Goddard Space** Flight Center, spacecraft management, experimenter; Applied Physics Laboratory, Johns Hopkins Univ., spacecraft prime contractor; Univ. of Illinois, Pennsylvania State Univ., Stanford Univ. and NBS Central Radio Propagation Laboratory, experimenters; NASA Langley Research Center, launch vehicle management; Ling-Temco-Vought, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	F.T. Martin	NASA-GSFC
PS	I.H. Brace	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
RF Beacon	PI	L.J. Blumle	NASA-GSFC
Langmuir Probe	PI	L. H. Brace	NASA-GSFC
Laser Reflector	PI	J.H. Berbert	NASA-GSFC
	CO	H.H. Plotkin	NASA-GSFC
	OI	C.C. Stephanides	NASA-GSFC
Navy Doppler	PI	R.J. Anderle	US Naval Surface Weapons Center

PEGASUS II

Launch Vehicle – Saturn I (SA-8), same as Pegasus I.

Spacecraft Description – Similar to Pegasus I. Total weight, 23,100 pounds; payload weight, about 3200 pounds.

Project Objectives – Continued micrometeoroid investigations begun under Explorer program and accelerated by Pegasus I; also intended to flight test modifications to spacecraft's meteoroid detection system.

Spacecraft Payload – Changes from Pegasus I design made to overcome short circuit problems encountered by that spacecraft. Detection panels divided into 62 logic groups; new fusing arrangement permitted disconnect of a single capacitor or logic group by ground command. Improved manufacturing techniques used to produce capacitor panels able to better withstand high temperatures encountered when spacecraft's wings directly faced the sun.

Project Results – Pegasus II was launched from Cape Kennedy on May 25, 1965 and placed in orbit of 314 to 466 miles at 32° inclination. Spacecraft's wings deployed on schedule and two hits recorded first day in orbit. After 40 days of operation 73 penetrations had been reported – 45 hits on 1.5 mil panels, 9 on 8 mil panels and 14 on 19 mil panels. During first four weeks 36 capacitors malfunctioned and were disconnected either singly or with their logic group by ground command. But because of new fusing arrangement, NASA no longer considered panel shorting a serious problem. Pegasus II continued to provide good data. And as a result of Pegasus I and II data– confirmation of lower meteoroid density than originally expected – an Apollo spacecraft weight reduction of about 1000 pounds was planned.

Major Participants – NASA Marshall Space Flight Center, spacecraft and launch vehicle management; fairchild Hiller, spacecraft prime contractor; Adcole Corp., solar aspect sensor; G. T. Schjeldahl Corp., detector panels; TRW Systems, electron spectrometer; Chrysler, first stage prime contractor; Douglas, second stage prime contractor.

Key Spacecraft Personnel		Affiliation
PM	Unknown	Unknown
PS	J.B. Dozier, Jr.	NASA-MSFC

Experiment	Experiment Personnel		Affiliation
Micrometeorite	PI	R.J. Naumann	NASA-MSFC
	OI	K.S. Clifton	NASA-MSFC
Electron Spectrometer	PI	Unknown	Unknown
Thermal Surface Coating	PI	Unknown	Unknown

EXPLORER XXVIII (IMP C)

Launch Vehicle – Delta: Thor first stage with 170,000 pounds of thrust, 7500-pound-thrust second stage and solid propellant 5700-pound-thrust third stage. First two stages radio guided, third stage spin stabilized. Height, 90 feet.

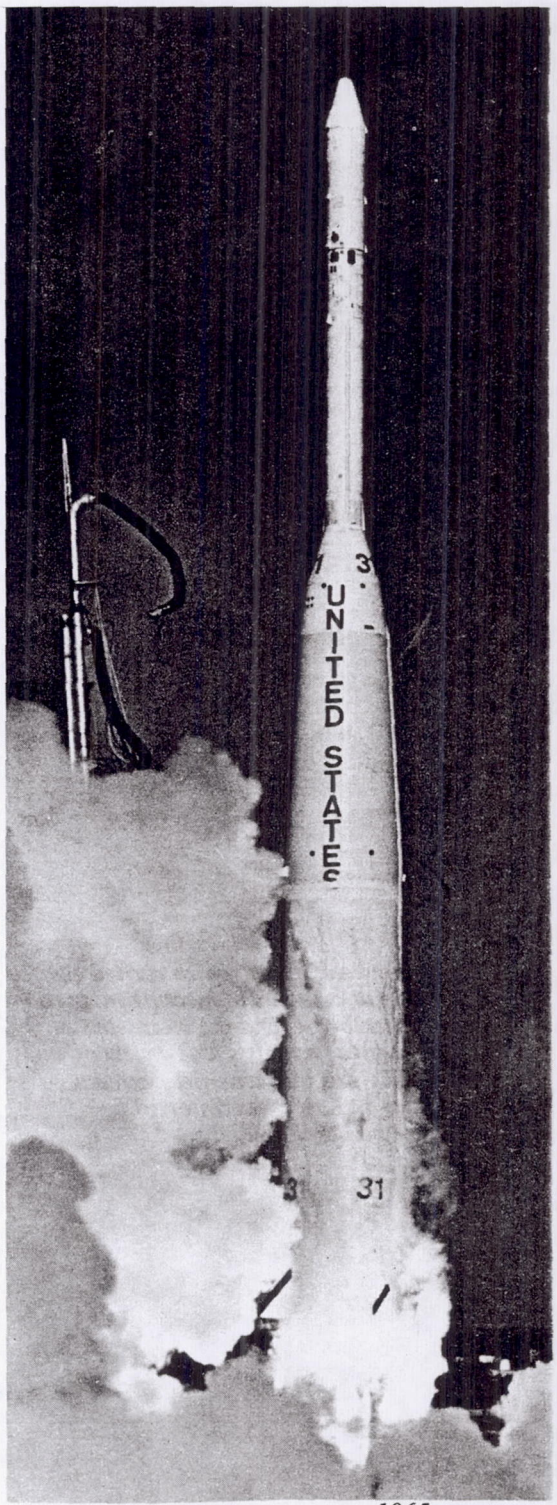
Spacecraft Description – Similar to Explorers XVIII and XXI. Main structure an octagon 28 inches across and 8 inches high. Magnetometer sphere mounted on telescopic 6-foot boom atop spacecraft and two magnetometers on 7-foot booms extended from body, along with four solar panels and four telemetry antennas. Weight, 130 pounds.

Project Objectives – Third Interplanetary Monitoring Platform (IMP) spacecraft. Explorer XXVIII designed to measure magnetic fields, cosmic rays and solar wind in region beyond earth's magnetosphere.

Spacecraft Payload – Instrumentation for nine experiments (all but magnetometers located in main body) included: rubidium vapor and two fluxgate magnetometers for magnetic field magnitude and direction measurements; low-energy charged particle detector, three particle telescopes, ion chamber and two geiger counter tubes to measure galactic and solar cosmic rays; and curved-plate electrostatic analyzer, grid device and thermal ion electron sensor for solar wind studies. Spacecraft communication system included PFM telemetry, 4-watt transmitter and digital data processor. Satellite spin stabilized, with 20 rpm design spin rate. Power supply of 38 watts provided by 6144 n-on-p solar cells and silver-cadmium batteries.

Project Results – Explorer XXVIII was launched May 29, 1965 from Cape Kennedy into highly elliptical orbit of 121 to 163,831 miles at 34° inclination, somewhat higher (and better) than planned apogee of 130,000 miles due to too-long third stage burn.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, spacecraft prime contractor, experimenter; Universities of California-Berkeley and Chicago, M.I.T. and NASA Ames Research Center, experimenters; Douglas, launch vehicle prime contractor.

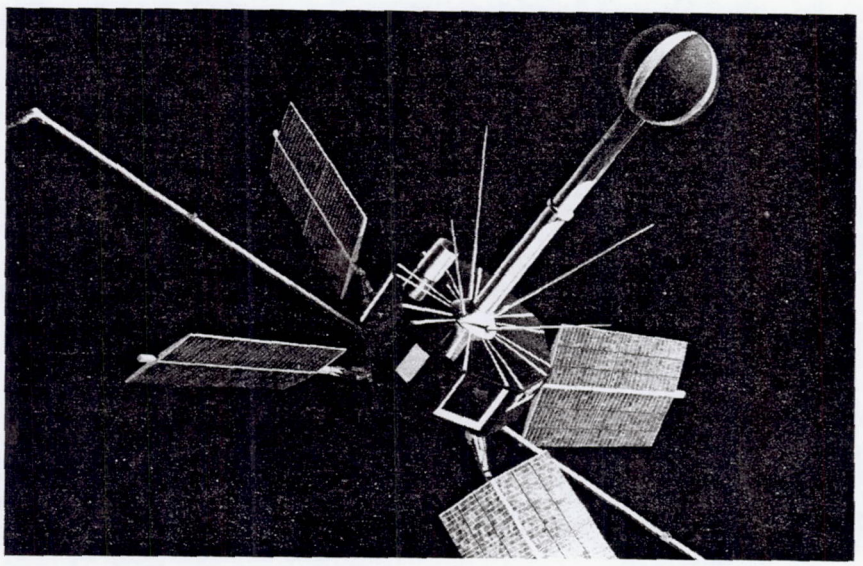


Delta 31 lifted off from Cape Kennedy, Fla. at 7:00 a.m. EST on May 29, 1965 to jettison Explorer XXVIII, the Interplanetary Monitoring Platform (IMP-C).

1965

Key Spacecraft Personnel		Affiliation
PM	P. Butler	NASA-GSFC
PS	F.B. McDonald	NASA-GSFC
CO	C.J. Creveling	NASA-GSFC
CO	D. Stewart	NASA-GSFC
CO	E.J. Pyle	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Retard. Poten. - Anal, E+P	PI	G.P. Serbu	NASA-GSFC
Magnetometers	PI	N.F. Ness	NASA-GSFC
C. R. Protons (R vs DE/DX)	PI	J.A. Simpson	University of Chicago
	OI	C.Y. Fan	University of Arizona
	OI	G. Gloeckler	University of Maryland
Cosmic Rays (E vs DE/DX)	PI	F.B. McDonald	NASA-GSFC
Total Ionization Experiment	PI	K.A. Anderson	University of California, Berkeley
	OI	G.H. Pitt	
Electrostatic Analyzer	PI	J.H. Wolfe	NASA-ARC
Faraday Cup	PI	H.S. Bridge	Massachusetts Institute of Technology
Rubidium Vapor Magnetometer	PI	N.F. Ness	NASA-GSFC
Orthogonal Geiger Mueller Counter	PI	F.B. McDonald	NASA-GSFC
	OI	G.H. Ludwig	NOAA-NESS
	OI	G.H. Ludwig	



A closeup view of IMP which carried eight scientific instruments to measure magnetic fields, cosmic rays, and the solar wind in space. It gave physicists a new view of how the Earth's magnetic field extends into space and becomes distorted by the Sun's powerful influence.

GEMINI IV

Launch Vehicle – Titan II, same as Gemini III.

Spacecraft Description – Similar to Gemini III. Consumables for longer mission increased weight to 7862 pounds.

Project Objectives – Primary purpose was to evaluate spacecraft and astronaut performance on four-day mission. Secondary experiments included first U.S. extra-vehicular activity (EVA) and rendezvous attempt with Titan II second stage.

Spacecraft Payload – Crew of command pilot James A. McDivitt, 35, and pilot Edward H. White II, 34. In addition to basic spacecraft systems, similar to Gemini III, the following EVA equipment was carried: emergency oxygen chest pack, 25-foot umbilical/tether line, compressed gas maneuvering unit, two cameras and thermal gloves. Sixteen meals of 2500 calories per day carried.

Project Results – Gemini IV was launched from Cape Kennedy on June 3, 1965 and placed in orbit of 100 to 175 miles at 32° inclination. Orbit raised to 103 to 180 miles during hour-long, unsuccessful attempt to rendezvous with second stage. Effort given up early on second revolution (NASA now counts revolutions – the number of times spacecraft passes over launch site's longitude – instead of orbits on extended manned flights) after 42% of fuel supply had been depleted. EVA then delayed from second to third revolution to give astronauts adequate time to prepare for experiment. White donned special gear and pressurized his suit at 3.7 psi, McDivitt depressurized spacecraft and opened hatch, then White propelled himself into space with his gas gun. Its fuel supply was exhausted after three minutes and the astronaut spent remainder of 21-minute excursion maneuvering all around the spacecraft by pulling on the tether and twisting his body. He suffered no disorientation during EVA, and found the experience exhilarating. White's pulse was 150 at beginning of experiment and rose to 178 just before return to spacecraft. Some difficulty was encountered resealing hatch, but working together the astronauts finally closed it. Next 30 hours spent in drifting flight to conserve fuel, then a series of medical, engineering, scientific and military experiments conducted. McDivitt reported seeing three satellites during flight. On 48th revolution the on-board computer became inoperative, requiring zero-lift ballistic re-entry used in Mercury program. Re-entry sequence initiated on 62nd revolution (orbit 66) with perigee lowered from 99 to 48 miles; retrorockets fired 12 minutes later. Each astronaut experienced about 8g during re-entry. Gemini 4 landed 56 miles short of intended impact area, after flight time of 97 hours, 56 minutes. McDivitt and White were recovered by helicopter and flown to USS Wasp, where they were pronounced in good condition.

Major Participants – NASA Manned Spacecraft Center, project management; NASA Goddard Space Flight Center, space tracking and data acquisi-

tion; McDonnell, spacecraft prime contractor; IBM and Honeywell, inertial guidance system; Rocketdyne, attitude and re-entry control systems; Garrett Corp., environmental control system; Collins Radio, communication system; Electro-Mechanical Research, telemetry system; Thiokol, retrorockets; Northrop Ventura, parachute recovery system; USAF Space Systems Division, launch vehicle management; Martin, launch vehicle integration; U.S. Navy, recovery task management.



Astronaut Edward H. White II prepares to enter Gemini IV spacecraft during test at Cape Kennedy.

Experiment	Experiment Personnel	Affiliation
Synoptic Terrain Photos	PI P.D. Lowman, Jr.	NASA-GSFC
Synoptic Weather Photos	PI K. Nagler	National Meteorological Center
Proton Electron Spectrum	PI J.R. Marback	Lockheed Electronics
Tri-Axis Magnetometer	PI W.D. Womack	NASA-JSC
2-Color Earth Limb. Photo.	PI M. Petersen	Massachusetts Institute of Technology
Dose Radiation Measure	PI Unknown	Unknown

TIROS X

Launch Vehicle – Delta, same as OSO C.

Spacecraft Description – Cylindrical, 18-sided polygon, 42 inches in diameter and 22 inches high. Solar cells covered top and sides, 18-inch receiving antenna was mounted on top and four whip antennas extended from base. Weight, 280 pounds.

Project Objectives – Maximum coverage of storm-breeding areas during 1965 hurricane and typhoon season. First U.S. Weather Bureau-funded Tiros; considered an interim operational satellite.

Spacecraft Payload – Television system employed two ½-inch vidicon cameras mounted on satellite's base. Cameras provide more than 400 photos daily, each of 640,000-square-mile area with resolution of about two miles at picture center. Two tape recorders employed for photo storage prior to readout to stations in Alaska or Virginia. Spacecraft spin-stabilized at 10 rpm. Spin axis attitude controlled from ground to be vertical with earth at 20°N, area where most tropical storms are born. Power supplied by 9100 p-on-n solar cells.

Project Results – Tiros X was launched from Cape Kennedy on July 2, 1965. Dog-leg maneuvers during first stage burn and after second stage burn placed satellite in sun-synchronous orbit of 458 to 517 miles at 98.6°. In this retrograde orbit Tiros X drifted westward about one degree a day – the same rate and direction as the earth moves around the sun – with maximum lighting for photography and battery charging. Good photographs were being received from both cameras.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; Weather Bureau, data analysis and distribution; Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	R.M. Rados	NASA-GSFC
PS	Aerospace and Meteorology Division	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	Ness Staff	NOAA-NESS

PEGASUS III

Launch Vehicle – Saturn I: 1,504,000-pound-thrust S-I first stage, 90,000-pound-thrust S-IV second stage and unpressurized instrument unit with inertial guidance system. Boilerplate Apollo command and service modules and launch escape tower were mounted atop vehicle with Pegasus housed within service module at launch. Height, 188 feet.

Spacecraft Description – Two "wings," each 14 x 48 feet, extended from open-truss rectangular center section which remained attached to Saturn's second stage. Each wing consisted of seven hinged frames, spring loaded to unfold in accordion fashion with deployment rate controlled by scissors linkage driven by electric motor. Experiment payload weight was 3200 pounds; total orbital vehicle – about 70 feet long – weighed 23,100 pounds.

Project Objectives – Final spacecraft in Pegasus program to collect data on frequency and size of meteoroids in near-earth environment.

Spacecraft Payload – Total of 208 panels, each 20 x 40 inches, were mounted in wing frames. Use of both sides of panel provided more than 2300 square feet of flat plate capacitor detection surface. Each panel composed of polyurethane foam core with aluminum-mylar-copper laminated skin. Three aluminum thicknesses, to measure three levels of impact energy, used in these capacitor sheets: 0.0015-inch on 16 panels, 0.008-inch on 34 panels and 0.16-inch on 366 panels. Panels were divided into 62 logic groups, with fusing arrangement to permit disconnect of a single capacitor or logic group by ground command. Detection system designed so that a micrometeoroid penetration would temporarily discharge capacitor sheet and resulting pulse stored in spacecraft's memory system. Solar and earth aspect sensors provided directional data. Second experiment, 48 detachable aluminum "coupons," was added to spacecraft for possible removal by a Gemini or Apollo astronaut; wing frames were coated with luminous paint to make spacecraft easier to recognize. Spacecraft electronics, including digital command system, located in cannister within center section. Thermal louvers controlled cannister temperature. Power supplied by 25,200 n-on- p solar cells on four panels on center section.

Project Results – Pegasus III was launched from Cape Kennedy on July 30, 1965. Tenth (and final) consecutive successful Saturn I test flight placed Pegasus III in orbit of 323 to 336 miles at 29° inclination, and also injected 10,100-pound boilerplate Apollo module into separate orbit. TV camera mounted on launch vehicle provided good views of exhaust plumes. Pegasus III has worked well; by December 21 there had been 59 hits on 16-mil panels, 14 on 8-mil panels and 123 on 1.5-mil panels. In a preliminary Pegasus program report, NASA indicated flux of small particles was less than expected, flux of large particles more than expected and flux of medium-sized particles about as predicted.

Major Participants – NASA Marshall Space Flight Center, spacecraft and launch vehicle management; Fairchild Hiller, spacecraft prime contractor;

G. T. Schjeldahl Co., detector panels; Adcole Corp., solar aspect sensor; TRW Systems, electron spectrometer; Chrysler, first stage contractor; Douglas, second stage contractor.

Key Spacecraft Personnel		Affiliation
PS	J.B. Dozier, Jr.	NASA-MSFC
PM	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
Micrometeorite	PI	R.J. Naumann	NASA-MSFC
	OI	K.S. Clifton	NASA-MSFC
Electron Spectrometer	PI	R.A. Potter	NASA-MSFC
Thermal Surface Coating	PI	Unknown	Unknown

GEMINI V

Launch Vehicle – Modified Titan II: 430,000-pound-thrust first stage and 100,000-pound-thrust second stage. Both stages used storable hypergolic liquid fuels and were radio guided. Height, 109 feet.

Spacecraft Description – Conical vehicle with two components: re-entry module made up of three sections – cabin, re-entry control and rendezvous and recovery; adapter module with two sections – retrograde and equipment. Titanium employed as principal re-entry module structural material, with nickel alloy and beryllium used for external shingles. Adapter module constructed primarily of magnesium. Re-entry module 39 inches in diameter at top, 90 inches at base; adapter module 90 inches in diameter at top, 10 feet at base. Total height, 18.4 feet. Weight, about 7000 pounds.

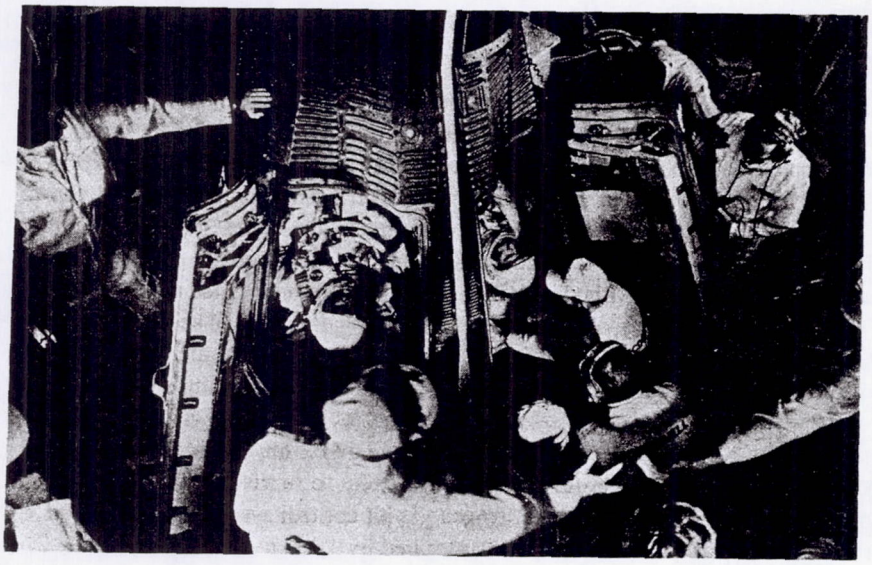
Project Objectives – Three primary objectives: 1) study effects of eight-day mission on two-man crew, 2) evaluate spacecraft performance on long-duration mission and 3) test rendezvous guidance and navigation system using radar evaluation pod (REP). Seventeen experiments scheduled: five medical, six scientific, one engineering and six DOD technological tests.

Spacecraft Payload – Crew of command pilot L. Gordon Cooper, Jr., 38, and pilot Charles Conrad, Jr., 35. Most non-medical experiments involved photography – 16mm sequence camera, 70mm camera and three 35mm cameras with interchangeable 200mm and 1270mm telephoto lenses carried. Rendezvous radar system used L-band inferometer-type radar with one transmitting and three receiving antennas mounted on spacecraft's front end. REP, mounted on the adapter section, was a 76-pound optical and electronic duplicate of the Agena planned for use in later Gemini rendezvous and docking missions. Spacecraft's environmental control system provided 100% oxygen environment at 5.0 psia. Orbit attitude and maneuver system used 16 jets with thrusts of 25, 85 and 100 pounds. Re-entry control system included 16 small thrusters to maintain attitude during firing of four solid retrorockets and through re-entry. Oxygen-hydrogen fuel cell power supply used for first time. Three meals per day (2750 calories) of bite-sized and rehydratable food carried for each astronaut.

Project Results – Gemini V was launched August 21, 1965 from Cape Kennedy and placed in orbit of 100 to 215 miles at 32.6° inclination. Early malfunction of fuel cell oxygen supply's heater element threatened to curtail mission as failure prevented pressurization of oxygen supply at 850 psia. As a result, REP was ejected 2 hours into flight but only limited useful experience gained in radar system operation. Oxygen pressure dropped finally to low of 65 psia (well above 22.2 psia minimum) after 4 hours of flight, then slowly rose for duration of mission providing sufficient power at all times. Most of experiment schedule was completed and a large volume of photographs, medical, radiation and other data acquired. Two Minuteman I launches from Vandenberg AFB and tropical storm Doreen were observed. Rendezvous maneuvers were conducted with an imaginary Agena. Minor fuel cell and thruster problems cropped up late in flight, but only a threatening tropical storm in recovery area was sufficient to curtail mission – by one revolution. Gemini V re-entered after 120 revolutions, establishing a space endurance record of 190 hours, 55 minutes. Splash down in the west

Atlantic was 103 miles short due to ground-based computer program error. Astronauts were soon picked up by helicopter and taken to Lake Champlain recovery carrier. Their only evident signs of eight days in orbit were stiffness and a case of dandruff. Extensive post flight examinations showed crew to be in good health. Flight demonstrated man's ability to adapt to weightlessness over an extended period, then readapt easily to 1 g environment.

Major Participants – NASA Manned Spacecraft Center, spacecraft management; NASA Goddard Space Flight Center, spacecraft tracking and data acquisition; McDonnell, spacecraft prime contractor; IBM and Honeywell, inertial guidance system; Rocketdyne, attitude and re-entry control systems; Garrett Corp., environmental control system; Collins Radio, communication system; Electro-Mechanical Research, telemetry system; GE, fuel cells; Thiokol, retrorockets; Northrop Ventura, recovery parachutes; Westinghouse, rendezvous radar system, REP; AF Space Systems Division, launch vehicle management; Martin, launch vehicle integration; U.S. Navy, recovery task force.



Gemini V astronauts L. Gordon Cooper, command pilot (left), and Charles Conrad, Jr., pilot (right) enter the spacecraft prior to launch on August 21, 1965.

Experiment	Experiment Personnel	Affiliation
Zodiacal Light Photography	PI E. Ney	Unknown
Synoptic Terrain Photos	PI P.D. Lowman, Jr.	NASA-GSFC
Synoptic Weather Photos	PI K. Nagler	National Meteorological Center
Cloud Top Spectrometer	PI F. Saiedy	University of Maryland
	OI J.C. Alishouse	NOAA-NESS
Celestial Radiometry	PI Unknown	Unknown
Space Object Radiometry	PI B. Brentnall	USAF Systems Command
Visual Threshold	PI S.O. Duntley	Scripps Institute of Oceanography

OSO C

Launch Vehicle – Delta: Thor first stage with 170,000 pounds of thrust, 7500-pound-thrust second stage and solid propellant 5760-pound-thrust third stage. First two stages radio guided, third stage spin-stabilized. Height, 90 feet.

Spacecraft Description – Two main sections: spinning base or "wheel" section and top or "sail" section. Wheel section 44 inches in diameter and 9 inches high; three 30-inch arms extended from section with 6-inch sphere mounted on end of each arm. Sail section nearly semicircular with radius of 22 inches. Solar cells and pointing instruments mounted on side designed to face sun. Weight, 620 pounds.

Project Objectives – Third in series of eight solar observatories, OSO C was intended to maintain continuity of observations during 11-year solar activity cycle.

Spacecraft Payload – Nine experiments totaling 242 pounds, two pointed at sun from sail section – UV scanning monochromator to measure 250-1300A region and X-ray spectrometer to study various wavelengths from 1 to 400A, and seven experiments in wheel section – thermal radiation emissivity detector, earth albedo telescopes, direction radiometer telescopes, celestial gamma-ray detector, solar X-ray detector, cosmic ray charge spectrum detector and solar X-ray telescope. Biaxial attitude control system designed to maintain solar pointing accuracy of 1 minute of arc during daylight. Wheel section intended to spin at 30 rpm, with spin axis maintained perpendicular to sun direction. Electric motor mounted on shaft connecting satellite's two sections, driving at equal but opposite rate to that of wheel, designed to orient sail section toward sun. OSO C featured three major improvements over earlier OSOs; improved ground command system to receive up to 94 commands, torque coil to augment nitrogen gas jet control system and improved roll aspect measuring device. Power supplied by 1860 n-on-p solar cells.

Project Results – OSO C was launched from Cape Kennedy on August 25, 1965. Delta's third stage ignited prematurely, failed to reach planned acceleration. Satellite thus entered Atlantic Ocean rather than planned 350-mile circular orbit at 33° inclination.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, experimenter; Ball Brothers Research Corp., spacecraft prime contractor; AF Cambridge Research Laboratories, M.I.T., NASA Ames Research Center and Univs. of California (San Diego), Michigan and Rochester, experimenters; Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	L. Hogarth	NASA-GSFC
PS	W.E. Behring	NASA-GSFC

OGO II

Launch Vehicle – TAT-Agena D: Thor first stage augmented by three solid motors for total thrust of 333,000 pounds, 16,000-pound-thrust Agena D second stage. First and second stages radio guided. Total height, 86 feet.

Spacecraft Description – Aluminum body 68 inches long and 33 inches square, with 12 appendages including two 22-foot, three 6-foot and one 4-foot experiment booms; antenna, attitude control and orbital plane experiment package (OPEP) booms; and two large solar panels with a solar-oriented experiment package (SOEP) on each panel. Fully deployed, OGO II was 59 feet long and 20.5 feet across solar panels. Extension of 60-foot radio noise antenna increased span to 80.5 feet. Weight, 1118 pounds.

Project Objectives – To perform simultaneous, correlated investigations of near-earth space phenomena on an inter-disciplinary basis. Results should help explain time-dependent relationship in galactic, interplanetary and planetary events, with emphasis on solar-terrestrial relationships. Planned mission lifetime, one year.

Spacecraft Payload – Twenty experiments weighed 210 pounds and were divided into six areas of investigation: magnetic field measurements – rubidium vapor and triaxial search coil magnetometers; cosmic ray experiments – ionization chamber, scintillation-Cerenkov detector and scintillation telescope detector; auroral and airglow studies – geiger counter, phosphor scintillation counter, two photometers, ionization chambers and UV spectrometer; atmospheric and ionospheric measurements – Bayard-Alpert ionization gauge, Paul massen-filter mass spectrometer, Bennett RF mass spectrometer, planar retarding potential analyzer and micrometeoroid time-of-flight and momentum detector; solar radiation experiments – ionization chambers and scanning spectrometer; and radio measurements – galactic emissions receiver, VLF receiver with inflatable 9.5-foot loop antenna and VLF receiver with 10-foot dipole antenna. Spacecraft systems included earth-stabilization attitude control system with infrared horizon scanners, two sun sensors, argon gas jets and reaction wheels. Gyro control and wabble gear drive employed to maintain OPEPs in required direction and wabble gear drive used for solar panel alignment. Communication system handled 254 different ground commands, stored up to 86 million bits of data and transmitted at up to 128,000 bits per second. Louvers on sides and one end of main body provided active thermal control. Power supplied by more than 32,000 n-on-p solar cells.

Project Results – OGO II was launched from Vandenberg AFB on October 14, 1965. Injected into orbit of 260 to 941 miles at 87° inclination (somewhat higher than planned), spacecraft successfully deployed its booms. But OGO II's horizon scanners occasionally drifted off earth lock as the spacecraft passed over equatorial region, apparently due to a cold air mass above equator. Repeated earth reacquisition depleted gas supply after 10 days. Instead of then tumbling, as expected, OGO II has been able to orient its solar panels toward the sun and slowly nutate around its long axis. Nine-

teen experiments are returning useful data on a duty cycle of about 30%, as power is built up following favorable sun angle on solar panels.

Major Participants – NASA Goddard Space Flight Center, spacecraft management, experimenter; TRW Systems, spacecraft prime contractor; AF Cambridge Research Laboratories, Dartmouth College, Jet Propulsion Laboratory, Kitt Peak National Observatory, Rice Univ., Stanford Univ., U.S. Naval Research Laboratory and Univs. of California (Los Angeles), Chicago, Colorado, Iowa, Michigan, Minnesota and Paris, experimenters; NASA Lewis Research Center, launch vehicle management; Douglas, first stage contractor; Lockheed, second stage contractor.

Key Spacecraft Personnel		Affiliation
PM	W.E. Scull	NASA-GSFC
PS	N.W. Spencer	NASA-GSFC
MG	C.D. Ashworth	NASA Headquarters
SC	R.F. Fellows	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Radio Astronomy 2, 2.5 MHz	PI	F.T. Haddock	University of Michigan
	CO	W. Potter	University of Michigan
VLF Receivers (012-100 KHz)	PI	R.A. Helliwell	Stanford University
	OI	L.H. Rorden	Devlco Incorporated
	OI	J.J. Angerami	Stanford University
VLF Receiver	PI	M.G. Morgan	Dartmouth College
Search-Coil Magnetometer	PI	E.J. Smith	NASA-JPL
	OI	R.E. Holzer	University of California, Los Angeles
Rubidium Vapor Magnetometer	PI	J.C. Cain	NASA-GSFC
	OI	R.A. Langel	NASA-GSFC
Cosmic Ray Ionization	PI	H.R. Anderson	Rice University
	OI	V.H. Neher	California Institute of Technology
Energetic Particle Survey	PI	J.A. Simpson	University of Chicago
	OI	E.C. Stone	California Institute of Technology
	OI	C.Y. Fan	University of Arizona
Galactic + Solar Cosmic Ray	PI	W.R. Webber	University of New Hampshire
10-100 keV Electron + Proton Scintillator	PI	R.A. Hoffman	NASA-GSFC
Airglow Study	PI	E.I. Reed	NASA-GSFC
	OI	J.E. Blamont	CNRS-SA
Geo Lyman Alpha	PI	P.W. Mange	US Naval Research Laboratory

Experiment	Experiment Personnel		Affiliation
Airglow Study	PI	C.A. Barth	University of Colorado
	OI	L.J. Wallace	Kitt Peak National Observatory
	OI	E.F. Mackey	Packard-Bell Corporation
Neutral Particle + Ion Composition	PI	L.M. Jones	University of Michigan
	OI	R.J. Leite	University of Michigan
Micrometeorites	PI	C.S. Nilsson	Flinders University of Southern Australia
	OI	D. Wilson	Smithsonian Astrophysical Observatory
Ionospheric Composition	PI	H.A. Taylor, Jr.	NASA-GSFC
	OI	N.W. Spencer	NASA-GSFC
Solar X-Rays	PI	R.W. Kreplin	US Naval Research Laboratory
	OI	T.A. Chubb	US Naval Research Laboratory
	OI	H.D. Friedman	US Naval Research Laboratory
Solar UV Spectrometer	PI	H.E. Hinteregger	USAF Geophysical Laboratory
	OI	D.E. Bedo	USAF Geophysical Laboratory
Cyl. Electrostatic Analyzer (Trap. Part)	PI	J.A. Van Allen	University of Iowa
	OI	L.A. Frank	University of Iowa
	OI	S.M. Krimigis	Applied Physics Laboratory
	OI	T.P. Armstrong	University of Kansas
	CO	H. Kiel	University of Iowa
Positive Ion Study	PI	J.L. Donley	NASA-GSFC
	OI	R.E Bourdeau	NASA-GSFC
Neutral Particle Study	PI	G.P. Newton	NASA-GSFC
Ion Wake Study	PI	F.T. Haddock	University of Michigan
	OI	H. Weil	US Naval Research Laboratory
	OI	R.G. York	US Naval Research Laboratory
Trapped + Dumped Elect.	PI	J.A. Van Allen	University of Iowa
	OI	L.A. Frank	University of Iowa

EXPLORER XXIX (GEOS-2, Geodetic Explorer A)

Launch Vehicle – Initial use of Thrust-Augmented Improved Delta (TAD) Thor first stage with three strap-on solid propellant motors, total thrust of 333,550 pounds; new "fat tank" 7800-pound-thrust second stage, extending burn time to 400 seconds; and solid propellant 5760-pound-thrust third stage. First two stages radio guided, third stage spin-stabilized. Height, 92 feet.

Spacecraft Description – Octagonal aluminum shell with eight-sided truncated pyramid on top, 48 inches across flats and 32 inches high. Extendable 60-foot gravity gradient boom of silver-plated beryllium-copper was mounted on top, with eddy current damper on end of boom. A 24-inch fiberglass hemisphere with broadband spiral antenna paint pattern projected from satellite's base. Xenon flash tubes, quartz-cube corner reflectors and 4-inch conical antenna also were mounted on base. Solar cells covered most of spacecraft's exterior. Weight, 385 pounds.

Project Objectives – As part of U.S. Geodetic Satellite Program, a joint NASA-DOD-Commerce Dept. effort, Explorer XXIX was designed to: 1) connect geodetic datums in a one-world datum and relate all surface datums to earth's common center of mass so that site locations can be determined in new three-dimensional coordinate system with accuracy of 33 feet or better, 2) map earth's irregular gravitational field and 3) correlate results from satellite's five geodetic measurement systems.

Spacecraft Payload – Five geodetic systems were: 1) four xenon flash tubes, each emitting light of 1580 candle-seconds per flash, 2) 322 laser corner reflectors, 3) three doppler beacon transmitters on 162, 324 and 972 mc, 4) Secor range transponder to return ground signals on 224.5 and 449 mc and 5) range and range-rate transponder transmitting on 1705 mc. Satellite systems included gravity gradient stabilization system with despin rods to remove residual spin prior to boom deployment and a motor to adjust boom length. Three magnetometers and six calibrated solar cells provided attitude data. Satellite clock, memory computer, command and telemetry systems supported experiments. The 4992 n-on-p solar cells were divided into three independent power supplies, each with its own battery.

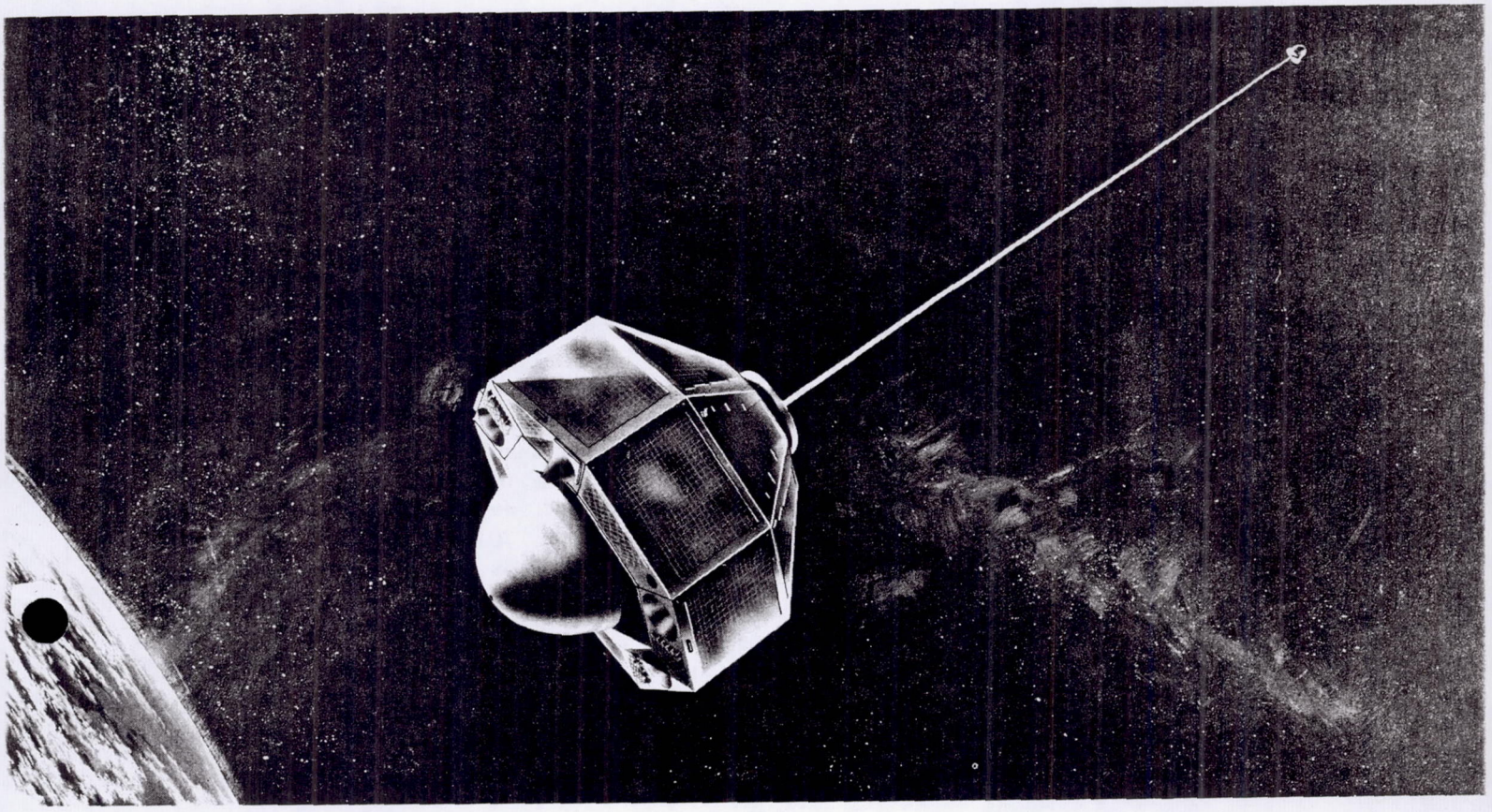
Artist's sketch of Explorer XXIX/GEOS-A over Florida peninsula and the shoreline of the eastern coast of the United States.



Project Results -- Explorer XXIX was launched during heavy rain at Cape Kennedy on November 6, 1965. Second stage burn was longer than planned, apparently because of loss of guidance lock due to rain; satellite entered somewhat higher orbit than planned, 692 to 1414 miles at 59 degrees inclination. Initial boom deployment resulted in spacecraft facing away from, rather than toward, earth. Boom was then retracted and again extended, this time with proper results. Explorer XXIX was operating as planned, transmitting excellent data. Various ground stations have successfully photographed spacecraft's flashing lights.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, experimenter; Applied Physics Laboratory,

Johns Hopkins Univ., spacecraft prime contractor; GE, gravity gradient system; AF Cambridge Research Laboratories, Army Office of Chief of Engineers, Bureau of Naval Weapons, Ohio State Univ., Smithsonian Astrophysical Observatory, U.S. Coast and Geodetic Survey and UCLA, experimenters.



Using an improved Delta launch vehicle, Explorer XXIX/GEOS-A was sent to outer space to help provide new geodetic data about the Earth. Some of this data helped improve sighting of satellite tracking stations.

Key Spacecraft Personnel		Affiliation
PM	C.J. Finley	NASA Headquarters
PS	J.P. Murphy	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Optical Beacon System	PI	R.E. Williston	Applied Physics Laboratory
Laser Corner Reflector	PI	H.H. Plotkin	NASA-GSFC
Doppler System	PI	R.J. Anderle	US Naval Surface Weapons Center
Secor (US Army) (sequential collation of range)	PI	J.S. McCall	USA, Office Chief of Engineers
NASA Range and Rate	PI	J.H. Berbert	NASA-GSFC
NASA Minitrack	PI	J.M. Kohout	NASA-GSFC

EXPLORER XXX

Launch Vehicle – Solid propellant Scout: 100,000-pound-thrust Algol IIB first stage, 63,100-pound-thrust Castor I second stage, 22,600-pound-thrust Antares II third stage and 6400-pound-thrust Altair II fourth stage. First three stages inertially guided, fourth stage spin-stabilized. Height, 72 feet.

Spacecraft Description – Two 24-inch hemispheres separated by 3½-inch equatorial band. Four telemetry antennas in turnstile array and 12 photometers mounted on midsection. Six 11-inch circular solar cell panels mounted symmetrically on hemispheres. Weight, 125 pounds.

Project Objectives – To monitor solar X-rays and ultraviolet emissions during final portion of 1964-65 International Quiet Sun Years (IQSY).

Spacecraft Payload – Ion chambers and geiger counters employed for measurements in overlapping X-ray bands between 0.5 and 60A. UV radiation in 1080-1350A region recorded by four ion chambers. Spacecraft spin-stabilized at 60 rpm. Two low-thrust ammonia vapor jets maintained spin rate and spin axis control, based on input from two sun sensors. Communication system included two command receivers, digital data storage unit, analog transmitter operated continuously and digital transmitter operated on command. Special coating applied to highly polished shell for passive thermal control. Solar cells supplied six watts power.

Project Results – Explorer XXX was launched November 19, 1965 from Wallops Island and placed in orbit of 440 to 548 miles at 60° inclination. The satellite was working satisfactorily, with data being acquired by NRL plus foreign stations in 13 countries. Minimum useful lifetime of one year planned.

Major Participants – NASA Wallops Station, project coordination; Naval Research Laboratory, spacecraft prime contractor, experimenter; NASA Goddard Space Flight Center, tracking services; NASA Langley Research Center, launch vehicle management; Ling-Temco-Vought, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	M.J. Aucremanne	NASA Headquarters
PS	R.W. Kreplin	US Naval Research Laboratories

Experiment	Experiment Personnel		Affiliation
Solar Radiation	PI	R.W. Kreplin	US Naval Research Laboratories

ISIS-X, ALOUETTE II AND EXPLORER XXXI

Launch Vehicle – Thor-Agena B: 170,000-pound-thrust first stage and 16,000-pound-thrust second stage programmed for two burns. First stage radio guided; second stage inertially guided, but with spin-table for Alouette II spin up and programmed to roll at 4 rpm for Explorer XXXI spin up. Height, about 86 feet.

Spacecraft Description – Alouette II, Alouette I's backup flight model – oblate spheroid 42 inches in diameter and 34 inches high, with its surface covered by solar cells. Two sets of beryllium-copper dipole antennas, one pair 75 feet long and second set 240 feet long, extended from midsection, five whip antennas projected from top and two short electrostatic probe rods extended from base. Weight, 320 pounds. Explorer XXXI: Octagon 30 inches across and 25 inches high. Solar cells covered 15% of surface. A 21-inch spherical ion mass spectrometer extended from top and pair of electrostatic probes projected from sides. Weight, 218 pounds.

Project Objectives – Alouette II, a follow-on to the successful Alouette I, and Explorer XXXI were intended to make related studies of ionospheric composition and temperature variations with time, altitude and latitude as they orbited in close proximity.

Spacecraft Payload – Alouette II: Repeated Alouette I's four experiments– sounding of ionosphere's topside with swept-frequency system in 0.2 to 13.5 mc range using long dipole antennas, cosmic noise measurements in same frequency band, whistler experiment in VLF spectrum and six particle detectors. Fifth Alouette II experiment, a pair of Langmuir electrostatic probes, was duplicated on Explorer XXXI to measure electron densities and temperatures and plasma phenomena resulting from voltages induced along Alouette II's dipole antennas. Spacecraft was spin-stabilized and powered by 6480 n-on-p solar cells. Explorer XXXI: In addition to the Langmuir probe, spacecraft carried seven instruments – thermal ion and electron experiments, electron temperature experiment, spherical ion mass spectrometer, high-resolution magnetic ion mass spectrometer and two energetic electron current monitors. Data acquisition in real time and on command only. Spin rate of 3 rpm and spin axis attitude perpendicular to orbital plane maintained by magnetic system with ground control and input from sun sensor and three-axis magnetometer.

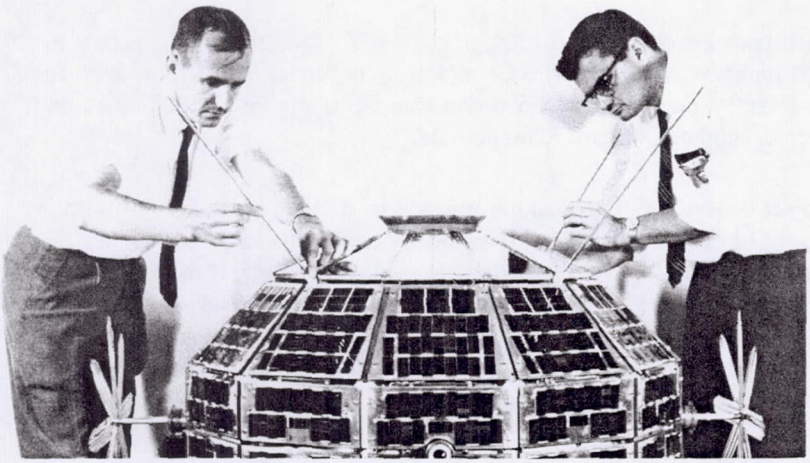
Project Results – Launched from Vandenberg AFB on November 29, 1965, Alouette II and Explorer XXXI were placed in near-duplicate orbits of 310 miles to 1850 miles at 80° inclination. All Alouette II and all but one Explorer XXXI experiments were working well, providing excellent data from regions of the ionosphere never before investigated.

Major Participants – Canadian Defence Research Telecommunications Establishment, Alouette management, prime contractor, experimenter; Canadian

National Research Council, Alouette experimenter; de Havilland Aircraft, Alouette sounding antennas; RCA Victor, Alouette major sub-contractor; NASA Goddard Space Flight Center, Explorer management, experimenter; Applied Physics Laboratory, Johns Hopkins Univ., Explorer prime contractor; University College (London) and Naval Research Laboratory, Explorer experimenters; NASA Lewis Research Center, launch vehicle management; Douglas, first stage contractor; Lockheed, second stage contractor.

Key Spacecraft Personnel		Affiliation
Alouette II		
PE	C.A. Franklin	Communication Research Centre
PM	E.D. Nelsen	NASA-GSFC
PS	G.L. Nelms	Defence Research Establishment
PC	J.H. Chapman	Communication Research Centre
MG	F.W. Gaetano	NASA Headquarters
SC	E.R. Schmerling	NASA Headquarters
MG	J.S. Johnson	Communication Research Centre
CO	J.H. Whitteker	Communication Research Centre
Explorer XXXI		
PC	G.C. Johnson	Unknown
PM	C.D. Florida	Communication Research Centre
PM	E.D. Nelsen	NASA-GSFC
PS	I. Paghis	Communication Research Centre
PS	J.E. Jackson	NASA-GSFC
SC	E.R. Schiffmacher	NOAA

Experiment	Experiment Personnel		Affiliation
Alouette II			
Sweep Frequency Sounder	PI	J.H. Whitteker	Communication Research Centre
	OI	J.E. Jackson	NASA-GSFC
	OI	J.W. King	Appleton Laboratory
	OI	L. Colin	NASA-ARC
	OI	J. Turner	Ionospheric Prediction Service
	OI	C. Taieb	CNET



The Canadian-built Alouette II spacecraft prior to launch from the Western Test Range. It was a joint project of NASA and the Canadian Defence Research Board.

Experiment	Experiment Personnel		Affiliation
	OI	O. Holt	Auroral Observatory
	OI	G.L. Nelms	Defence Research Establishment
	OI	Y. Ogata	Radio Research Laboratory
	OI	R. Raghavarao	Physical Research Laboratory
	OI	G.E.K. Lockwood	Communication Research Centre
VLF Receiver	PI	J.S. Belrose	Communication Research Centre
	OI	F.H. Palmer	Communication Research Centre
Radio Noise, 2-13.5 MHz	PI	T.R. Hartz	Communication Research Centre
Energetic Particle Detector	PI	I.B. McDiarmid	National Research Council of Canada
Langmuir Probe	PI	L.H. Brace	NASA-GSFC
Explorer XXI			
Planar Ion-Electron Trap	PI	E.J. Maier	NASA-GSFC
Langmuir Probe	PI	L.H. Brace	NASA-GSFC
Electron Temperature	PI	A.P. Willmore	University of Birmingham
Ion Mass Spectrometer	PI	A.P. Willmore	University of Birmingham
Magnetic Ion Mass Spectrometer	PI	J.H. Hoffman	University of Texas, Dallas
Planar Ion Trap	PI	E.J. Maier	NASA-GSFC
Electron Current	PI	E.J. Maier	NASA-GSFC

GEMINI VII

Launch Vehicle – Titan II, same as Gemini V.

Spacecraft Description – Similar to Gemini V. Two modifications to support rendezvous mission with Gemini VI: transponder installed on front end of re-entry module and two acquisition lights mounted 180° apart on adapter module. Weight, 8000 pounds.

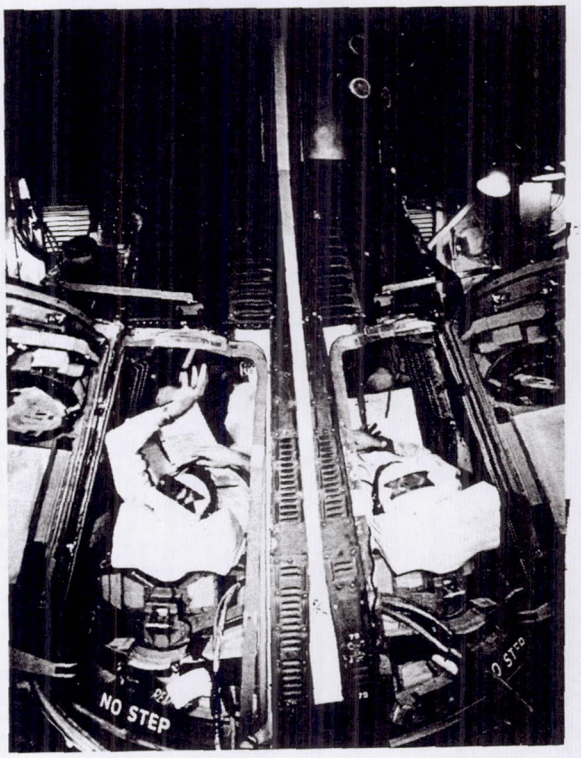
Project Objectives – Original purpose was to study effects of long-duration (up to 14 days) space flight on two-man crew, plus carry out some 20 experiments, 14 repeated from earlier Gemini missions and six new experiments – three medical tests including calcium balance study, two navigation tests and laser optical communication test. Service as target vehicle for Gemini VI was added to Gemini VII's objectives due to scrub of October rendezvous and docking mission.

Spacecraft Payload – Crew of command pilot Frank Borman, 37, and James A. Lovell, Jr., 37. Two 16mm movie cameras and 70mm camera with 80mm and 250mm lenses carried. Rendezvous transponder weighed less than 50 pounds, was designed to receive signals from Gemini VI's rendezvous radar system and return them at specific frequency and pulse width. On-board laser transmitter used four gallium arsenide injection lasers designed to produce 16 watts of light at 9000A. Spacecraft systems similar to Gemini V, except fuel cell and environmental control system oxygen supplies were linked so that one system could pressurize the other if needed. Lightweight (16 pounds), removable pressure suits worn for first time. Four menus of three meals (2400 calories) each alternated throughout flight.

Project Results – Gemini VII was launched from Cape Kennedy on December 4, 1965 and injected in orbit of 100 to 204 miles at 28.9° inclination. A 20-minute station-keeping exercise successfully conducted with launch vehicle's second stage prior to orbital insertion. Perigee raised to about 143 miles on third orbit to insure orbital lifetime of 15 days. First five days spent conducting experiments, then orbit circularized at 185 miles in preparation for rendezvous with Gemini VI. Launched December 15, Gemini VI-A rendezvoused with Gemini VII on scheduled fourth orbit. Gemini VII's principal function was to orient its transponder toward Gemini VI-A prior to rendezvous and fly a station-keeping formation during rendezvous. Both Gemini VII crew members maneuvered their spacecraft around Gemini VI to gain rendezvous flight experience, but maneuvers were limited to conserve attitude control system's fuel supply. Crew completed 75% of their experiment schedule, including visual and radiation signature tracking of submarine-launched Polaris A3, descending Minuteman II re-entry vehicle and Gemini VI-A's thruster plumes. Laser test failed as crew couldn't spot ground-based argon gas laser beacon. About 150 millirads of radiation measured within spacecraft for duration of flight. New pressure suits worked well; considerable flight time spent with one or both suits doffed, greatly increasing crew comfort and mobility. Lovell, who spent more time in shirtsleeve configuration than Borman, slept better and had a lower minimum heart-beat rate. Minor malfunctions related to fuel cells and attitude control thrusters occurred but did not hamper mission. Re-entry came after

206 revolutions, 14 days and 330 hours, 36 minutes – a new endurance record. Impact was within six miles of recovery carrier Wasp in west Atlantic, most accurate Gemini landing to date. Both crew members were in good condition. Initial examinations indicated most effects of weightlessness level off after a week or so of flight, as the responses and return-to-normal of Gemini VII crew closely resembled Gemini V's eight-day flight experience.

Major Participants – NASA Manned Spacecraft Center, spacecraft management; NASA Goddard Space Flight Center, spacecraft tracking and data acquisition; McDonnell, spacecraft prime contractor; IBM and Honeywell, inertial guidance system; Rocketdyne, attitude and re-entry control systems; Garrett Corp., environmental control system; Collins Radio, communication system; Electro-Mechanical Research, telemetry system; GE, fuel cells; Thiokol, retrorockets; Northrop Ventura, recovery parachutes; Westinghouse, rendezvous transponder, REP; AF Space Systems Division, launch vehicle management; Martin, launch vehicle integration; U.S. Navy, recovery task force.



Gemini VII astronauts Frank Borman (left) and James A. Lovell (right) prior to launch on December 4, 1965. The 330 hour, 35 minute flight included the first rendezvous mission in space.

Experiment	Experiment Personnel	Affiliation
Synoptic Terrain Photos	PI P.D. Lowman, Jr.	NASA-GSFC
Synoptic Weather Photos	PI K. Nagler	National Meteorological Center
Celestial Radiometry	PI Unknown	Unknown
Star Occultation Navigation	PI E. Vallerie	USAF Avionics Laboratory
Space Object Radiometry	PI B. Brentnall	USAF Systems Command
Proton Electron Spectrometer	PI J.R. Marback	Lockheed Electronics
Tri-Axis Magnetometer	PI W.D. Womack	NASA-JSC
Landmark Contrast Measurement	PI Unknown	Unknown

FRENCH IA

Launch Vehicle – Scout, same as Explorer XXX.

Spacecraft Description – Octagonal center section with truncated octagonal prisms mounted on top and bottom, 27 inches across corners and 52 inches high including magnetic field antenna boom atop satellite. Four telemetry antennas extended from top section, two 14-foot electric field dipoles (with gold-plated spheres on ends of the four booms) deployed from midsection and 19-inch electron density probe projected from bottom. Solar cells covered 85% of surface, remaining area painted white. Weight, 132 pounds.

Project Objectives – To study VLF radio wave propagation in various regions of ionosphere and magnetosphere and to measure electron densities near spacecraft for correlation with VLF data. Secondary study areas were: transmission coefficient of the lower ionosphere (D and E layers), VLF radio wave propagation along magnetic force lines from one hemisphere to another and impedance of the four electric field antennas.

Spacecraft Payload – Two telemetry systems used in measurements of VLF electric and magnetic field components. TM 1 received signals on 16.8 kc from French station at Ste. Assise, France, and retransmitted via PAM/FM/PM transmitter on 136.800 mc to NASA STADAN stations in England and South Africa equipped with French receivers; TM 2 received 24 kc signals from U.S. Navy station at Balboa, Canal Zone, and retransmitted five experiment data simultaneously by wideband FM/PM transmitter on 136.350 mc to similar ground stations in Peru and Ecuador. TM 1 operated continuously, TM 2 on command. Optical sun sensor and triaxial magnetometer furnished attitude reference data. Electron density probe consisted of a parallel-plate capacitor sensor. Spacecraft spin-stabilized at 12 rpm and featured passive thermal control. Maximum power of 17 watts supplied by 3840 n-on-p solar cells.

Project Results – French-IA was launched from Vandenberg AFB on December 6, 1965 and placed in near-circular orbit of 458 to 484 miles at 76° inclination. Initial operations were quite successful; experiment lifetime planned for three months. In addition to STADAN network, five French Iris and Diane stations in Africa and France were used for tracking and data acquisition.

Major Participants – CNES (National Center for Space Studies), spacecraft management, prime contractor; Nord-Aviation, spacecraft structure and antennas; Spacecraft Inc., TRW Systems and Westinghouse, spacecraft telemetry systems; CNET (National Center for Telecommunications Studies) and Univ. of Birmingham (U.K.), experimenters; NASA Goddard Space Flight Center, tracking and data acquisition services; NASA Langley Research Center, launch vehicle management; Ling-Temco-Vought, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	X. Namy	CNES
PS	L.R. Storey	CNET
PM	S.R. Stevens	NASA-GSFC
PS	J. Conn	Unknown
PS	R.W. Rochelle	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
VLF Receiver	PI	L.R.O. Storey	Ionospheric Research Group
	OI	C. Renard	University of Bourges
	OI	M.P. Aubrey	CNET (National Center for Telecommunications Studies)
Capacitance Probe	PI	J. Sayers	University of Birmingham

GEMINI VI/VI-A

Launch Vehicle – Titan II, same as Gemini V.

Spacecraft Description – Similar to Gemini V. Rendezvous radar system mounted on front end of spacecraft. Carried 669 pounds of fuel for extensive rendezvous maneuvers. Total weight, about 7000 pounds.

Project Objectives – Principal purpose was to rendezvous with Gemini VII. Pre-flight definition of rendezvous specified matching orbital altitudes, inclinations and velocities. Three photography and radiation experiments also planned.

Spacecraft Payload – Crew of command pilot Walter M. Schirra, Jr., 42, and Thomas P. Stafford, 35. Three cameras similar to Gemini VII's payload carried. Rendezvous radar system provided data on range, range-rate and bearing angle to Gemini VII to on-board inertial guidance system computer, which displayed orbital adjustments required for rendezvous on incremental velocity indicator. Spacecraft systems similar to Gemini V. Two 2600-calorie menus carried.

Project Results – After two earlier aborts – on October 25, 1965 due to Agena target vehicle failure and on December 12, 1965 due to premature release of a launch vehicle inhibitor plug – Gemini VI-A was launched December 15, 1965 from Cape Kennedy into orbit of 100 to 162 miles at 28.9° inclination. Gemini VI-A initially trailed Gemini VII by about 1200 miles. Beginning at launch plus 1 hour, 34 minutes, command pilot Schirra initiated series of six major thruster burns ranging from 14.2 to 60.8 fps and several minor "tweak" burns. Radar acquisition occurred at range of 170 miles. Rendezvous achieved at 5 hours, 50 minutes into flight – with spacecraft 120 feet apart. This gap was ultimately and repeatedly closed to 1 foot during numerous station-keeping exercises. Only half of the fuel supply allocated for rendezvous maneuvers, about 175 pounds, was spent. Spacecraft remained in close formation (within 100 feet) for 20.4 hours, then Gemini VI-A's orbit was adjusted for re-entry. Spacecraft landed about 12 miles from carrier "Lake Champlain" after 16 revolutions and 25 hours, 51 minutes. Both astronauts were recovered in excellent condition.

Major Participants – NASA Manned Spacecraft Center, spacecraft management; NASA Goddard Space Flight Center, spacecraft tracking and data acquisition; McDonnell, spacecraft prime contractor; IBM and Honeywell, inertial guidance system; Rocketdyne, attitude and re-entry control systems; Garrett Corp., environmental control system; Collins Radio, communication System; Electro-Mechanical Research, telemetry system; Thiokol, retro-rockets; Northrop Ventura, recovery parachutes; Westinghouse, rendezvous radar system, REP; AF Space Systems Division, launch vehicle management; Martin, launch vehicle integration; U.S. Navy, recovery task force.

Key Spacecraft Personnel		Affiliation
MG	G.E. Mueller	NASA Headquarters
PM	W.C. Schneider	NASA Headquarters
PM	C.W. Mathews	NASA Headquarters
SC	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
Synoptic Terrain Photos	PI	P.D. Lowman, Jr.	NASA-GSFC
Synoptic Weather Photos	PI	K. Nagler	National Meteorological Center
Dose Radiation Measure	PI	Unknown	Unknown

PIONEER VI

Launch Vehicle – Thrust-Augmented Improved Delta (TAD), same as Explorer XXIX. First Delta use for interplanetary mission.

Spacecraft Description – Cylinder 37 inches in diameter and 35 inches high. Three 64-inch booms deployed from midsection, with a magnetometer, wobble damper and orientation nozzle on ends of their respective booms. A 52-inch mast containing high-gain and two low-gain antennas projected from one end. Dual frequency antenna used in radio propagation experiment deployed from other end. Spacecraft structure primarily of aluminum, with sides of cylinder covered with solar cells except for experiment view band at midsection. Weight, 140 pounds.

Project Objectives – Designed to operate in solar orbit to provide data on solar wind, interplanetary magnetic field, solar physics and basic interactions of high-energy charged particles and magnetic fields. Nominal mission lifetime, six months.

Spacecraft Payload – Six experiments totaled 35 pounds – highest ratio of scientific instrument weight to overall spacecraft weight of any interplanetary spacecraft. Experiments divided into three groups: single axis fluxgate magnetometer for magnetic field data; plasma cup detector, quadrispherical plasma analyzer and radio propagation detector for solar wind studies; and cosmic ray anistropy detector and cosmic ray telescope for cosmic ray measurements. Spacecraft systems included S-band communication system with redundant 8-watt TWTs for transmission range in excess of 50 million miles; transmission rates varied from 512 bits per second near earth to 8 bits per second at maximum range. Data storage capacity was 14,232 bits, about 19 hours of spacecraft and experiment data. Nitrogen gas jet attitude control system with input from four sun sensors oriented spin-stabilized (60 rpm) spacecraft normal to ecliptic plane. Experiments designed to sweep ecliptic plane. Sun sensor defined direction of experiment sensors with respect to spacecraft/sun line. Power supplied by 10,368 n-on-p solar cells – 80 watts at earth distance and about 90 watts at 0.8 AU. Spacecraft electronics mounted on circular platform in center of vehicle; thermal louvers below platform controlled internal temperatures. Spacecraft design minimized and controlled magnetic field due to materials and currents to assure high accuracy measurements of low magnetic fields. Pioneer VI's magnetic field – 0.5 gamma at 80 inches from center of spacecraft – significantly smaller than any previous spacecraft.

Project Results – Pioneer VI was launched December 16, 1965 from Cape Kennedy. Final earth-sun orientation achieved 44 hours later at 230,000 miles from earth. Spacecraft systems and experiments were functioning well. Initial data indicated a relatively slow solar wind and fairly constant magnetic fields, consistent with current "quiet" solar period. Launched toward the sun, Pioneer VI was expected to come within about 77 million miles of the sun after five months.

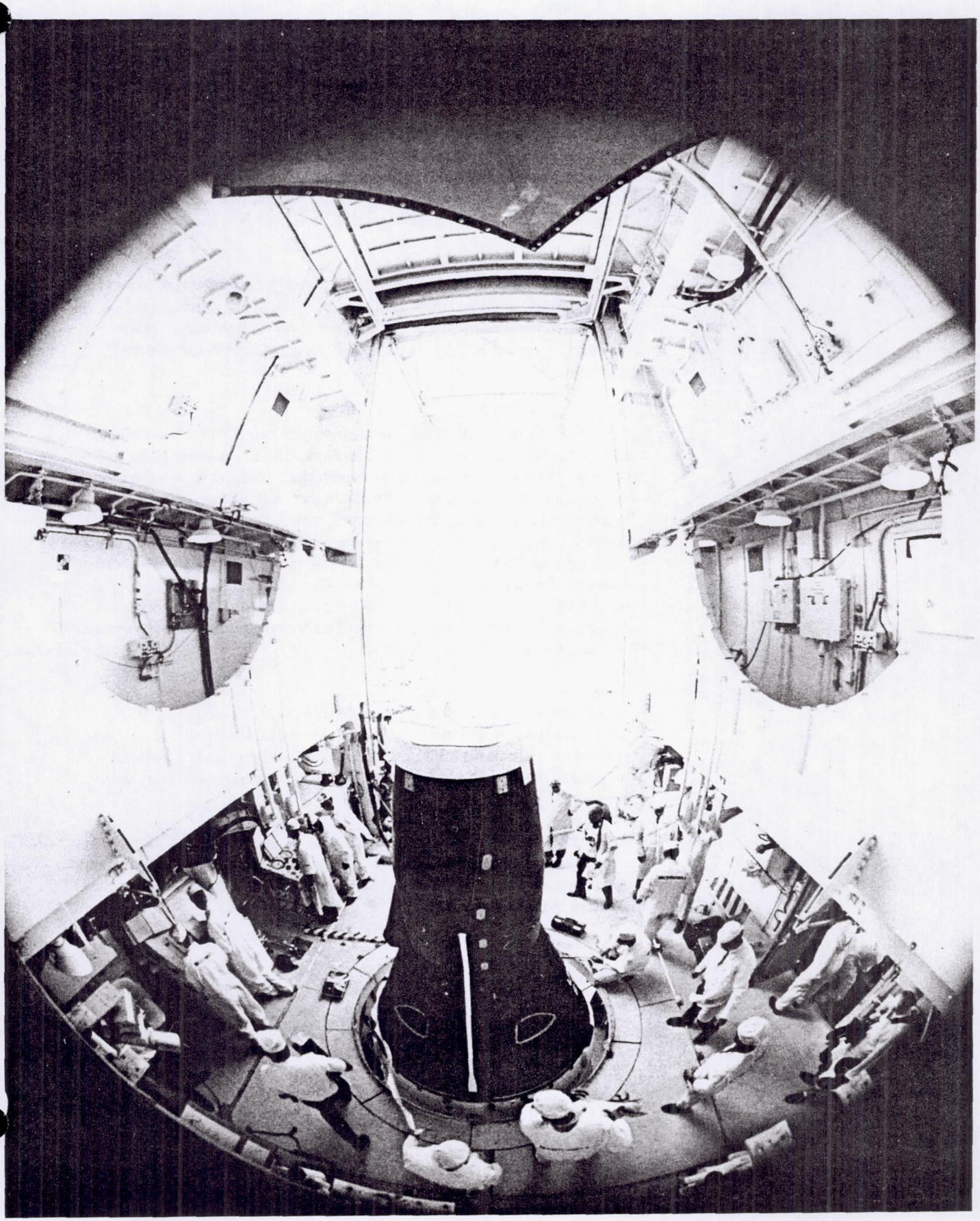
Major Participants – NASA Ames Research Center, spacecraft management, experimenter; TRW Systems, spacecraft prime contractor; Jet Propulsion Laboratory, Deep Space Network management; Chicago Univ., Graduate Research Center of the Southwest, M.I.T. and Stanford Univ., experimenters; NASA Goddard Space Flight Center, launch vehicle management, experimenter; Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	C.F. Hall	NASA-ARC
PS	J.H. Wolfe	NASA-ARC
CO	R.R. Nunamaker	NASA-ARC
CO	N.J. Martin	NASA-ARC
CO	N.A. Renzetti	NASA-JPL
CO	A.J. Siegmeth	NASA-JPL
MG	F.D. Kochendorfer	NASA Headquarters
SC	A.G. Opp	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Single Axis Magnetometer	PI	N.J. Ness	NASA-GSFC
Faraday Cup	PI	H.S. Bridge	Massachusetts Institute of Technology
	OI	A.J. Lazarus	Massachusetts Institute of Technology
	OI	F. Scherb	University of Wisconsin
Cosmic Ray Telescope	PI	C.Y. Fan	University of Arizona
	OI	J. A. Simpson	University of Chicago
	CO	G. Lentz	University of Chicago
	OI	J.E. Lamport	University of Chicago
Two Frequency Receiver	PI	V.R. Eshleman	Stanford University
	OI	T.A. Croft	SRI International
	OI	R.L. Leadabrand	SRI International
	OI	O.K. Garriott	NASA-JSC
	OI	A.M. Peterson	Stanford University
Cosmic Ray Detector	PI	K.G. McCracken	CSIRO
	OI	W.C. Bartley	National Academy of Sciences
	OI	U.R. Rao	ISRO Satellite Center
Electrostatic Analyzer	PI	J.H. Wolfe	NASA-ARC
Celestial Mechanics	PI	J.D. Anderson	NASA-JPL
Sup. Conjunction Faraday Rot.	PI	G.S. Levy	NASA-JPL
Spectral Broadening	PI	R.M. Goldstein	NASA-JPL
Relativity Investigation	PI	J.D. Anderson	NASA-JPL

Gemini X astronauts John W. Young and Michael Collins are in their spacecraft as launch personnel prepare for liftoff. Gemini X later rendezvoused and docked with Agena launch vehicle.

1966



ESSA I

Launch Vehicle – Delta: Thor first stage with 172,000 pounds of thrust, 7500-pound-thrust second stage and solid propellant 5760-pound-thrust third stage. First two stages radio guided, third stage spin stabilized. Height, 90 feet.

Spacecraft Description – Identical to Tiros configuration: cylindrical 18-sided polygon, 42 inches in diameter and 22 inches high. Two television cameras were mounted 180° apart on sides, 18-inch receiving antenna was mounted on top, solar cells covered top and sides and four transmitting whip antennas extended from baseplate. Weight, 305 pounds.

Project Objectives – First of two cartwheel Tiros Operational Satellites to form the initial global weather satellite system. ESSA I was intended to provide cloud cover photography to Weather Bureau's National Meteorological Center for use in daily weather analyses and forecasts distributed throughout world.

Spacecraft Payload – Television system employed two ½-inch, 500-line cameras, canted 26.5° on opposite sides of satellite's rotational plane to provide width coverage for full global observation. Cameras designed to provide more than 400 photos daily with resolution of about two miles at picture center. Onboard triggering system programmed cameras to take pictures only when facing earth. Two tape recorders, each capable of storing up to 48 pictures, used when satellite was beyond range of ground stations in Alaska and Virginia. Satellite spin rate of 10 rpm maintained by magnetic control system, backed up by solid propellant spin-up motors. Magnetic coil also used for attitude control, coupled with two infrared horizon sensors. Power supplied by 9100 n/p solar cells.

Project Results – Launched from Cape Kennedy on February 3, 1966, ESSA I was placed in retrograde orbit of 432 to 521 miles at 98° inclination. This sun-synchronous orbit permitted satellite to view weather in each area of globe each day, photographing a given area at same local time every day.

Major Participants – Environmental Science Services Administration, project management; NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; Douglas, launch vehicle prime contractor.

ESSA II

Launch Vehicle – Thrust Augmented Improved Delta (TAD): Thor first stage with three strap-on solid propellant motors and total thrust of 333,500 pounds, 7700-pound-thrust second stage and 5760-pound-thrust solid propellant third stage. First and second stages radio guided, third stage spin stabilized. Height, 92 feet.

Spacecraft Description – Similar to ESSA I. Weight, 290 pounds.

Project Objectives – Intended to complement ESSA I and complete initial global weather satellite system. ESSA II was designed to provide direct readout of cloud cover photos to local users equipped with low-cost receiving stations.

Spacecraft Payload – Major change from ESSA I was the inclusion of an automatic picture transmission (APT) system previously tested on Tiros VIII and Nimbus I. Two advanced 1-inch, 800-line cameras were mounted perpendicular to spin axis on opposite sides of satellite. APT system was designed to take and transmit a picture every 352 seconds – each photo covering an area 2000 miles on a side with two-mile resolution at picture center. ESSA II's camera system did not include photo storage capability. Camera triggering, power supply and control systems were similar to ESSA I, with spin rate maintained at 10.9 rpm.

Project Results – ESSA II was launched February 28, 1966 from Cape Kennedy and injected into near-circular, retrograde orbit of 843 to 885 miles at 101° inclination. In this orbit, satellite passes within 2100-mile picture reception range of APT ground stations on two or three orbits each day. Approximately 50 U.S. ground stations were in operation in various parts of world, plus some 30 foreign stations.

Major Participants – Environmental Science Services Administration, project management; NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; Douglas, launch vehicle prime contractor.

GEMINI VIII

Launch Vehicle – Titan II: 430,000-pound-thrust first stage and 100,000-pound-thrust second stage; radio guided. Height, 109 feet.

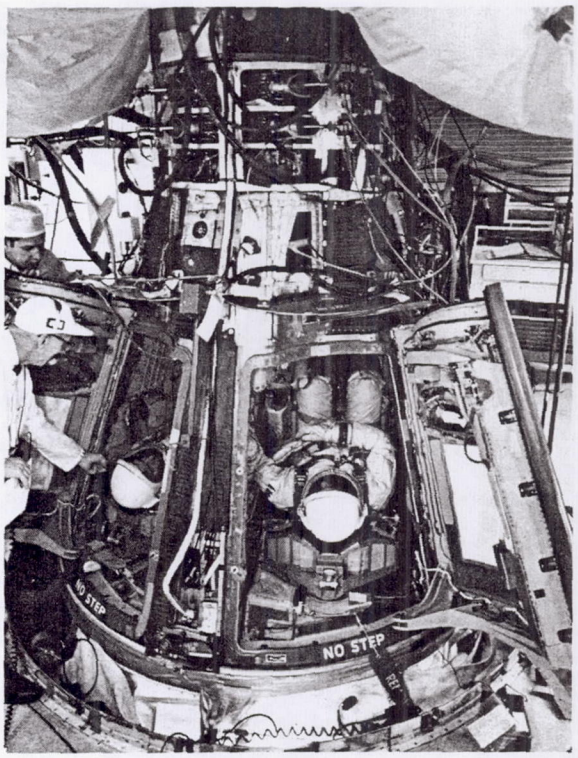
Spacecraft Description – Conical vehicle consisted of two components: re-entry module with cabin, re-entry control and rendezvous and recovery sections, and adapter module with retrograde and equipment sections. Titanium used as principal re-entry module structural material, with beryllium and nickel alloy employed for external shingles. Adapter module built primarily of magnesium. Re-entry module 39 inches in diameter at top, 90 inches at base; adapter module 90 inches in diameter at top, 10 feet at base. Total spacecraft height, 18.4 feet. Weight, 8351 pounds.

Project Objectives – Primary objectives were rendezvous and four docking tests with Agena D target vehicle and two hour, 40 minute extravehicular activity experiment. Ten experiments were carried on Gemini VIII – four technological, five scientific and one medical.

Spacecraft Payload – Crew of command pilot Neil A. Armstrong, 35, and pilot David R. Scott, 33. Pilot life support during EVA provided by 42-pound chest pack with 25-foot umbilical tether, 92-pound back pack mounted on the rear of the adapter section with 75-foot tether and freon-fueled maneuvering gun. Rendezvous radar system provided range, range-rate and bearing angle data to on-board inertial guidance computer which displayed output on incremental velocity indicator. New auxiliary tape memory subsystem included in guidance system. Other spacecraft systems included environmental control system with 100% oxygen environment at 5.0 psi. Orbit attitude and maneuver system (OAMS) used 16 jets with thrusts of 25, 85 and 100 pounds. Re-entry control system (RCS) included 16 25-pound-thrust engines to maintain attitude during firing of four solid 2500-pound-thrust retrorockets and through re-entry. Two hydrogen-oxygen fuel cells provided power. Bite-sized and rehydratable meals averaged 2770 calories per day.

Project Results – Gemini VIII's Agena target was launched by an Atlas D from Cape Kennedy on March 16, 1966 and injected into planned 185-mile circular orbit at inclination of 28.9°. Gemini VIII was launched 101 minutes later and placed in its scheduled orbit of 100 to 168 miles at inclination similar to target vehicle. Rendezvous was achieved on fifth orbit and, after a short station-keeping period, the first docking in space was smoothly accomplished six hours, 34 minutes into Gemini VIII's flight. Twenty-eight minutes later, as the crew prepared for powered maneuvers with 7000-pound Agena, combined vehicle went into violent yaw and roll tumble. Unable to bring the vehicle under control, astronaut Armstrong separated the spacecraft from Agena. Gemini VIII continued to tumble as a short circuit caused continuous firing of OAMS 25-pound roll thruster. Finally all 16 RCS thrusters were utilized to damp out roll and the spacecraft brought under control. About 75% of RCS fuel supply was used up, however, forcing de-

Gemini VIII backup crew Charles "Pete" Conrad, command pilot, and Richard F. Gordon, pilot, enter Gemini spacecraft for simulated test.



cision to cancel EVA experiment and recover Gemini VIII as soon as possible – after only 6½ orbits of scheduled three-day flight. Re-entry was achieved without incident as spacecraft landed after 10 hours, 42 minutes – within five miles of U.S.S. Leonard F. Mason and 500 miles southeast of Okinawa. Both crew members recovered in good condition. Partial data received on three experiments and a fourth experiment was left on Agena for eventual recovery on Gemini X mission.

Major Participants – NASA Manned Spacecraft Center, spacecraft management; NASA Goddard Space Flight Center, spacecraft tracking and data acquisition; McDonnell, spacecraft prime contractor; IBM and Honeywell, inertial guidance system; Westinghouse, rendezvous radar system; Rocketdyne, attitude and re-entry control systems; Garrett Corp., environmental control system; Collins Radio, communication system; Electro-Mechanical Research, telemetry system; General Electric, fuel cells; Thiokol, retrorockets; Northrop Ventura, recovery parachutes; AF Space Systems Division, launch vehicles management; Martin, Titan II integration; General Dynamics/Convair, Atlas prime contractor; U.S. Navy, recovery task force.

Key Spacecraft Personnel		Affiliation
MG	G. E. Mueller	NASA Headquarters
PM	W. C. Schneider	NASA Headquarters
PM	C. W. Mathews	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Synoptic Terrain Photos	PI	P. D. Lowman, Jr.	NASA-GSFC
Zodiacal Light Photos	PI	E. Ney	Unknown
Frog Egg Growth	PI	R. S. Young	NASA Headquarters
Cloud Top Spectrometer	PI	F. Saiedy	University of Maryland
Nuclear Emulsion	PI	M. M. Shapiro	U.S. Naval Research Laboratory
Micrometeorites	PI	C. L. Hemenway	Dudley Observatory
Cloud Photography	PI	K. Nagler	National Meteorological Center
	OI	S. Soules	NOAA-National Weather Service

OAO I

Launch Vehicle – Atlas-Agena D: 390,000-pound-thrust Atlas D first stage, 16,000-pound-thrust Agena D second stage. First stage radio guided, second stage inertially guided. As OAO I's diameter was larger than that of the Agena, a special shroud was employed to cover both the spacecraft and second stage. Height, 104 feet.

Spacecraft Description – Octagonal aluminum cylinder 10 feet long and seven feet wide. Experiments housed in four-foot central cylinder running length of the body. Sunshade mounted at top of experiment tube shielded instruments from direct solar rays. Two solar arrays of three panels each attached to opposite sides of spacecraft, giving OAO I a wingspread of 21 feet, as were two 9.5-foot balance weight booms. Weight, 3900 pounds.

Project Objectives – OAO I carried four experiments to study, for the first time over an extended period, the UV, X-ray and gamma ray regions from above obscuring and distorting effects of the earth's atmosphere.

Spacecraft Payload – Experiment instrumentation weighed 1000 pounds and included: 1) seven UV telescopes to view about 200 selected stars and nebulae in 1100 to 3000 A region, 2) high-energy gamma ray detector similar to device carried on Explorer XI, 3) gas proportional counter to define and map X-ray sources and 4) low-energy gamma ray detector to survey photon sources in 2 to 180 Kev range. Spacecraft attitude control system was designed to point OAO I with accuracy of one minute of arc ± 15 arc seconds for 50 minutes. System's sensors included six gimballed star trackers and one boresighted star tracker aligned with experiment optical axis, eight coarse and eight fine sun sensors, three rate gyros, stellar television camera and three torquing bars. Twelve primary gas jets, six secondary jets, three coarse reaction wheels and three fine reaction wheels used for stabilization. Communication and data handling system included wideband telemetry with redundant transmitters and 204,800-bit data storage capacity. Power supplied by 74,618 p/n solar cells and nickel-cadmium batteries; satellite required 405 watts average per orbit. Spacecraft's passive thermal control system isolated internal structure from external and internal heat sources.

Project Results – OAO I was launched April 8, 1966 from Cape Kennedy and placed in near-circular orbit of 496 to 502 miles at 35° inclination. Initial stabilization was achieved but on its second day in orbit the satellite's primary battery began to overheat and soon malfunctioned, rendering OAO I inoperative.

Major Participants – NASA Goddard Space Flight Center, spacecraft management, experimenter; Grumman, spacecraft prime contractor; General Electric, attitude control system; IBM, data handling subsystem; M.I.T. and Univ. of Wisconsin, experimenters; Cook Laboratories, Wisconsin experiment

contractor; Lockheed, experimenter, second stage contractor; NASA Lewis Research Center, launch vehicle management, General Dynamics/Convair, first stage contractor.

Key Spacecraft Personnel		Affiliation
PM	C.K. Zeimer	NASA-GSFC
PS	J.E. Kupperian, Jr.	NASA-GSFC

Experiment	Experiment Personnel	Affiliation
Broadband UV Photometry	PI A. D. Code	University of Wisconsin
Gamma-Ray Telescope	PI K. J. Frost	NASA-GSFC
Gamma-X-Ray Telescope	PI W. L. Kraushaar	University of Wisconsin
X-Ray Proportional Counter	PI P. C. Fisher	Lockheed Palo Alto

NIMBUS II

Launch Vehicle – TAT-Agena B: Thor first stage augmented by three strap-on solid motors, 333,550 pounds of thrust; Agena B second stage, 16,000 pounds of thrust. First stage employed inertial and radio guidance, second stage inertially guided. Height, 95 feet.

Spacecraft Description – Composed of three major elements: sensory ring lower section, hexagonal upper section and two large solar panels. Upper and lower sections connected by magnesium truss. Attitude control system housed in upper section, with solar panels attached to section. Sensory ring, five feet in diameter, contained meteorological instrumentation and spacecraft electronics. Spacecraft 10 feet tall, 11 feet across solar panels. Weight, 912 pounds.

Project Objectives – To provide global weather photography on 24-hour basis for meteorological research and operational use, provide infrared data for study of earth's heat balance and demonstrate 24-hour automatic picture transmission (APT) direct local readout capability.

Spacecraft Payload – Four sensor systems weighing total of 142 pounds were carried. Advanced vidicon camera system (AVCS) included three 1-inch cameras with 800-line resolution designed to photograph 800,000 square mile area, with delayed readout of up to 192 photos or direct APT readout. One APT camera with 800-line resolution covered area of two million square miles on continuous basis during daytime. High resolution infrared radiometer provided time and expected to yield variety of geophysical and atmospheric data including cloud height information. Five-channel medium resolution infrared radiometer carried to measure entire earth's heat balance budget every day. Clock and command system used to operate sensor systems. Earth-stabilization attitude control system employed horizon scanners, coarse sun sensors, yaw gyro, reaction wheels and freon gas jets. S-band transmitter utilized for photo transmission in addition to APT system's FM transmitter. Power supply included 10,500 n/p solar cells and nickel-cadmium batteries. Louvers on both sections employed for thermal control.

Project Results – Nimbus II was launched May 15, 1966 from Vandenberg AFB and placed in "high noon" retrograde orbit of 684 to 734 miles at 100° inclination. Sun-synchronous orbit provides ideal lighting conditions for picture taking. At the same time, Nimbus I and its sensors were working well; in first two months in orbit the spacecraft returned more than 150,000 photos. Less than 2% of attitude control system's gas supply was used during that period. About 150 APT ground stations, including 44 stations in 26 foreign countries, were receiving Nimbus I's pictures. Extensive infrared coverage of Atlantic hurricane breeding areas was planned during Nimbus I's six-month design lifetime.

Major Participants – NASA Goddard Space Flight Center, spacecraft management, prime contractor; General Electric, spacecraft structure, attitude control system, integration and test; RCA, power supply and camera systems; ITT, high resolution infrared radiometer; Hughes, medium resolution infrared radiometer; NASA Lewis Research Center, launch vehicle management; Douglas, first stage contractor, Lockheed, second stage contractor.

Key Spacecraft Personnel		Affiliation
PM	H. Press	NASA-GSFC
PS	W. P. Nordberg	NASA-GSFC
CO	G. J. Delio	NASA-GSFC
CO	P. J. Crossfield	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
AVCS	PI	J. R. Schulman	NASA-GSFC
API	PI	J. R. Schulman	NASA-GSFC
HRIR	PI	L. L. Foshee	USA Electronics Command
MRIR	PI	A. W. McCulloch	NASA-GSFC

EXPLORER XXXII (Atmosphere Explorer B)

Launch Vehicle – Delta, with new third stage: 172,000-pound-thrust Thor first stage, 7500-pound-thrust second stage and 5450-pound-thrust solid propellant FW-4 third stage. First two stages radio guided, third stage spin stabilized. Height, 90 feet.

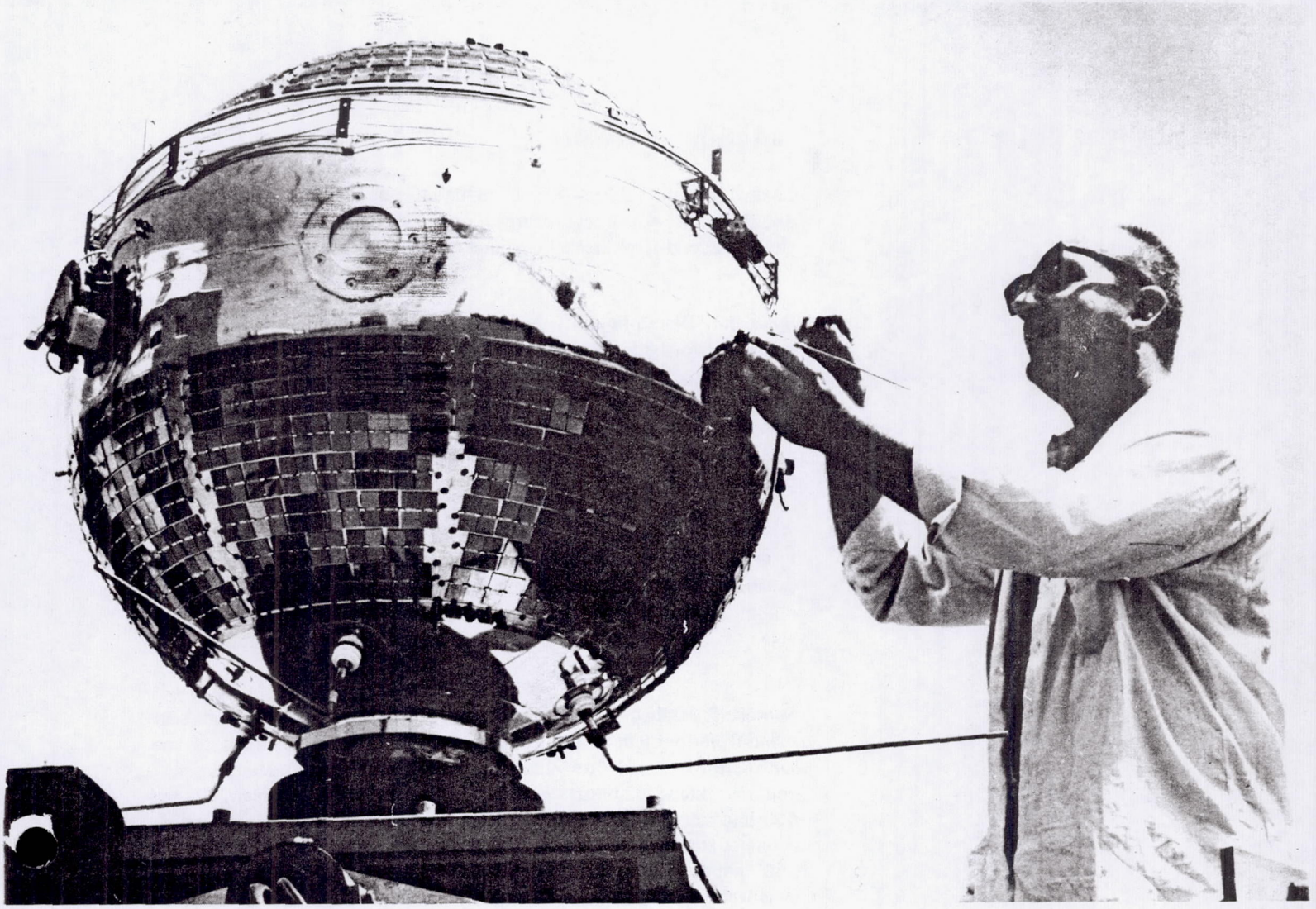
Spacecraft Description – Hermetically sealed sphere of 0.025-inch stainless steel, 35 inches in diameter. Twelve solar cell patches were bonded to satellite shell. Canted turnstile antenna array projected from bottom and two 18-inch electrostatic probes projected from opposite sides of sphere's equator. Weight, 495 pounds.

Project Objectives – Follow-on to Explorer XVII aeronomy satellite orbited in April 1963. Explorer XXXII's eight experiments were to measure temperatures, composition, densities and pressures and their variations with time of day, season and year to study upper atmosphere's physical processes. Secondary objective was to study short-term atmospheric perturbations caused by solar storms, primarily in auroral regions and South Atlantic magnetic anomaly area.

Spacecraft Payload – Experiment instrumentation included two neutral-particle mass spectrometers, ion mass spectrometer, three magnetron density gauges and two electrostatic probes. Optical aspect system provided orientation data during day and night. Internal pressure relieved by fuel cell system and motor-driven vacuum valve. Satellite spin stabilized at 30 rpm, with magnetic spin axis and spin rate control systems. Communication system included tape recorder and redundant PCM telemetry systems with 0.5-watt transmitters. Primary power supplied by silver-zinc batteries with 10,500 watt-hours capacity, augmented by 2064 solar cells. Satellite design lifetime, one year.

Project Results – Explorer XXXII was launched May 25, 1966 from Cape Kennedy. Second stage command cutoff failure resulted in much higher apogee than planned, 1629 vs. 750 miles, with perigee of 173 miles and 65° inclination. However, on-board programming of Explorer XXXII's sensors has been adjusted to compensate for higher apogee and all but two experiments functioned as planned.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, spacecraft prime contractor, experimenter; Budd Co., spacecraft shell; Douglas, launch vehicle prime contractor.



A technician of the NASA Goddard Space Flight Center attaches the probe of electron temperature experiment to the flight model of Atmosphere Explorer B. The spacecraft was being tested on a spin table to check out the spacecraft's optical aspect system.

Key Spacecraft Personnel		Affiliation
PM	N.W. Spencer	NASA-GSFC
PS	L.H. Brace	NASA-GSFC
SC	R.F. Fellows	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
RF Ion Mass	PI	H. C. Brinion	NASA-GSFC
	OI	H. A. Taylor, Jr.	NASA-GSFC
	OI	R. A. Pickett	NASA-GSFC
Neutral Magnetometer	PI	C. A. Reber	NASA-GSFC
Spectrometer	OI	J. E. Cooley	NASA-GSFC
Atmospheric Drag	PI	C. Wulf-Mathies	University of Bonn
	OI	L. G. Jacchia	SAO
Redhead Ionization Gauges	PI	G. P. Newton	NASA-GSFC
Electricity Temperature	PI	L. H. Brace	NASA-GSFC
and Density	OI	J. A. Findlay	NASA-GSFC

SURVEYOR I

Launch Vehicle – Atlas-Centaur: 390,000-pound-thrust Atlas D first stage, 30,000-pound-thrust high-energy Centaur second stage. First stage radio guided, second stage inertially guided. Height, 113 feet.

Spacecraft Description – Tubular aluminum frame supported propulsion systems, two thermal compartments, descent radars, two boom-mounted conical omnidirectional antennas, tripod landing gear with aluminum honeycomb foot pad on end of each leg and mast with planar antenna and solar panel mounted on top. Surveyor I was 10 feet high and 14 feet across its extended legs. Weight at launch, 2194 pounds; weight at lunar landing, 596 pounds.

Project Objectives – Initial engineering test flight to demonstrate spacecraft capability to perform midcourse and terminal maneuvers and to soft land on moon. Television payload intended to photograph lunar surface and crushable pads on two landing legs. First Atlas-Centaur operational flight.

Spacecraft Payload – Television survey camera was focused on earth command from four feet to infinity, with narrow- or wide-angle field of view and apertures from f/4 to f/22. Exposure time of 150 milliseconds also could be extended by earth command. Camera system returned 200- and 600-line pictures. Color filter wheel provided clear, colored or polarizing filters. Camera mounted nearly vertically, pointed at mirror that rotated 360° and tilted to reflect portions of two landing legs to above the horizon. Engineering evaluation instrumentation included temperature sensors, strain gauges and accelerometers. Spacecraft attitude and velocity control provided by automatic sun acquisition sensor, sun and Canopus sensors, inertial reference unit, altitude marking radar, inertia burnout switch, radar altimeter and doppler velocity sensors, flight control electronics and three pairs of nitrogen gas jets. Propulsion system included three liquid variable-thrust (each 30 to 104 pounds) vernier engines and solid propellant retrorocket with 8000 to 10,000 pounds of thrust. Retro was 36 inches in diameter, weighed 1377 pounds. Communication system employed two low-gain antennas for 200-line pictures, high-gain antenna for 600-line photos and redundant 10-watt transmitters and receivers, handled up to 256 commands and more than 200 spacecraft engineering measurements. Power supply of 3960 solar cells and silver-zinc batteries was designed to furnish minimum of 77 watts at 140°F and 57 watts at 239°F. Active thermal control provided for two electronic compartments, otherwise paint patterns, polished surfaces and insulation used for passive thermal control.

Project Results – Surveyor I was launched May 30, 1966 from Cape Kennedy and placed in a direct ascent lunar trajectory. Sixteen hours later vernier engines were fired for approximately 21 seconds to correct trajectory for landing in the southwest corner of planned Apollo landing zone. Terminal sequence operation was close to nominal flight plan: retro aligned with approach velocity vector at about 1000 miles above moon, altitude marking radar turned on at 200 miles, retro and vernier engine ignition at

47 miles, retro burn out and jettison at 37,000 feet with spacecraft velocity 250 mph, speed slowed by verniers to 5 fps above moon, and finally free fall to lunar surface. Surveyor I landed at about 12 fps, north of Flamsteed crater in Oceanus Procellarum (Ocean of Storms) at 2.5°S and 43.3°W – within 10 miles of midcourse aiming point. Flight time, 63.6 hours. One omnidirectional antenna boom that apparently failed to deploy prior to second stage separation extended upon landing. Surveyor I's first hour on the moon was spent performing engineering tests. Photography sessions were then initiated throughout remainder of lunar day. Some 10,338 photos were returned prior to nightfall on June 14. During its initial 12 days on the moon, the probe responded properly to approximately 100,000 commands. Surveyor I was able to withstand the first lunar night, and near high noon on its second lunar day, July 7, photos again were returned. On July 13, after total of 11,150 pictures had been transmitted, Surveyor I's mission was terminated due to a dramatic drop in battery voltage just after sunset. Preliminary results indicated Surveyor I landed in a dark, level area covered with craters up to several hundred yards in diameter and encircled by hills and low mountains. Surface in the landing area was composed of granular material of a very wide size range – from coarse blocks of rocks to smaller fragments set in matrix of particles too fine to be resolved by Surveyor I's camera. Spacecraft's landing pads penetrated the lunar surface to maximum depth of one inch.

Major Participants – Jet Propulsion Laboratory, spacecraft management, tracking; Hughes, spacecraft prime contractor; Ryan, radar altimeter and doppler velocity sensor; Thiokol, retro and vernier propulsion; Northrop, landing gear; NASA Lewis Research Center, launch vehicle management; General Dynamics/Convair, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	W. Eugene Giberson/Robert J. Parks/ Howard H. Haglund	JPL
PS	Leonard L. Jaffe	JPL
MG	Benjamin Milwitzky	

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	E. M. Shoemaker	California Institute of Technology
	OI	R. M. Batson	U.S. Geological Survey
Strain Gauge Data	PI	E. M. Christensen	NASA-JPL

GEMINI IX/IX-A

Launch Vehicle – Titan II, same as Gemini VIII.

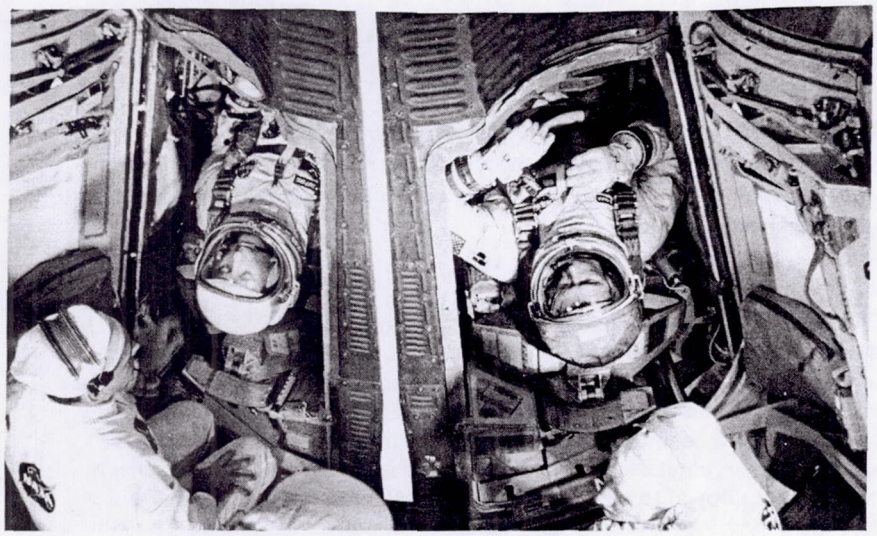
Spacecraft Description – Standard conical Gemini configuration, see Gemini VIII. Weight, 8268 pounds.

Project Objectives – Initial objectives were to perform three rendezvous and docking tests with Agena D target vehicle and two hour, 25 minute extravehicular activity experiment to evaluate astronaut maneuvering unit (AMU). First stage control system malfunction during Atlas-Agena D launch on May 17, 1966 prevented intended target vehicle from entering orbit. A 1700-pound augmented target docking adapter (ATDA) without propulsion was substituted for rescheduled Gemini IX-A mission. Basic project objectives remained the same. Six experiments – three scientific, two technological and one medical – were carried, but micrometeoroid impact package to have been mounted on Agena was eliminated.

Spacecraft Payload – Crew of command pilot Thomas P. Stafford, 35, and pilot Eugene A. Cernan, 32. Astronaut Cernan's EVA life support equipment included 42-pound chest pack with 25-foot umbilical tether and 166-pound AMU back pack with 125-foot tether. AMU included form-fitting seat and self-contained life support, communication, telemetry, propulsion and manual and automatic stabilization systems. Propulsion system utilized 12 small thrusters mounted on pack's corners, hydrogen peroxide fuel supply and thruster controls on two sidearm supports. Back pack was 32 inches high, 22 inches wide and 19 inches deep. AMU was mounted on rear of adapter section. Spacecraft systems similar to Gemini VIII.

Project Results — ATDA was launched June 1, 1966 from Cape Kennedy and successfully placed in circular 186-mile orbit at 28.9° inclination, but telemetry indicated its shroud failed to deploy. Attempt to launch Gemini IX about 100 minutes later was foiled by ground data transmission malfunction. Gemini IX subsequently was orbited on June 3, with initial parameters of 99 to 168 miles at ATDA's inclination. Rendezvous with ATDA was easily accomplished on third orbit and target's shroud malfunction confirmed from inches away. Various ground attempts to free shroud failed, thus Gemini IX was prevented from docking with its target. Flight plan then revised to conduct the two re-rendezvous maneuvers during Gemini IX's firsd day in orbit. Both equi-period, passive rendezvous without use of on-board radar and simulated Apollo LEM abort rendezvous from above target vehicle were successfully carried out, although the crew found it difficult to spot their target as it passed above light-colored desert areas on earth. EVA was conducted second day in orbit. Cernan expended about four times more energy than expected in evaluating tether dynamics and carrying out other maneuvers, and also experienced difficulty in maintaining orientation. Then his helmet visor fogged up while donning the AMU and that portion of EVA was cancelled. Cernan re-entered Gemini IX after two hours, 9 minutes, a new EVA endurance record. Re-entry was routinely accomplished after 47 orbits and 72 hours, 20 minutes of flight with a landing within 2.5 miles of planned impact point in west Atlantic. Both astronauts were in good condition following recovery.

Major Participants – NASA Manned Spacecraft Center, spacecraft management; NASA Goddard Space Flight Center, spacecraft tracking and data acquisition; McDonnell, spacecraft and ATDA prime contractor; IBM and Honeywell, inertial guidance system; Westinghouse, rendezvous radar system; Rocketdyne, attitude and re-entry control systems; Garrett Corp., environmental control system; Collins Radio, communication system; Electro-Mechanical Research, telemetry system; General Electric, fuel cells; Thiokol, retrorockets; Northrop Ventura, recovery parachutes; AF Space Systems Division, launch vehicles and AMU management; LTV, AMU contractor; Martin, Titan II integration; General Dynamics/Convair, Atlas prime contractor; U.S. Navy, recovery task force.



Astronauts Eugene A. Cernan (left) and Thomas P. Stafford (right) prepare to leave Gemini IX spacecraft after learning that Agena target vehicle had failed.

Key Spacecraft Personnel		Affiliation
MG	G. E. Mueller	NASA Headquarters
PM	W. C. Schneider	NASA Headquarters
PM	C. W. Mathews	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Zodiacal Light Photos	PI	E. Ney	Unknown
Micrometeorite Cratering	PI	C. L. Hemenway	Dudley Observatory
Airglow Photos	PI	M. J. Koomen	U.S. Naval Research Laboratory
Micrometeorites	PI	C. L. Hemenway	Dudley Observatory
Synoptic Terrain Photos	PI	P. D. Lowman, Jr.	NASA-GSFC
Cloud Photography	PI	K. Nagler	National Meteorological Center
	OI	S. Soules	NOAA-National Weather Service
Cosmic Ray Nuclear Emulsion	PI	C. E. Shapiro	U.S. Naval Research Laboratory
	OI	C. E. Fichtel	NASA-GSFC

OGO III

Launch Vehicle – Atlas-Agena B: 390,000-pound-thrust Atlas D first stage, 16,000-pound-thrust Agena B second stage. First stage radio guided, second stage inertially guided. Height, 107 feet.

Spacecraft Description – Aluminum body 68 inches long and 33 inches square, with 12 appendages: two 22-foot and four 4-foot experiment booms, high-gain antenna boom, two gas jet booms, orbital plane experiment package (OPEP) boom and two large solar panels with solar-oriented experiment packages (SOEP). Initially deployed, OGO III was 49 feet long and 20.5 feet wide, then 30-foot radio astronomy experiment antenna extended from one solar panel and 9.5-foot diameter VLF loop antenna was inflated at end of one long boom. Weight, 1135 pounds.

Project Objectives – Twenty-one experiments, largest number ever for a U.S. scientific spacecraft, were carried to obtain correlated data on geophysical and solar phenomena in the earth's atmosphere and magnetosphere and in interplanetary space.

Spacecraft Payload – Scientific instrumentation totaled 195 pounds and was divided into eight areas of investigation: cosmic rays (4 experiments), plasma (4), trapped radiation (2), magnetic fields (2), ionosphere (5), optical and radio emission (3) and micrometeoroids (1). Spacecraft systems included earth-stabilization attitude control with infrared horizon scanners, two sun sensors, argon gas jets and reaction wheels. Gyro control and wabble gear drive employed to maintain OPEPs in required direction and wabble gear drive used for solar panel alignment. Communication and data handling system handled 254 ground commands, stored up to 86 million bits of data and transmitted up to 128,000 bits per second. Power supplied by 32,256 n/p solar cells and nickel-cadmium batteries. Louvers on sides and one end of body provided active thermal control.

Project Results – OGO III was launched from Cape Kennedy on June 7, 1966 and placed in near-perfect orbit of 170 to 75,768 miles at 31° inclination. Spacecraft is operating as planned, returning data from all 21 experiments. Simultaneous measurements by OGOs I and III at different locations within magnetosphere, together with OGO II measurements in low earth orbit, provide opportunity for significant studies. Mission design lifetime, one year.

Major Participants – NASA Goddard Space Flight Center, spacecraft management, experimenter; TRW Systems, spacecraft prime contractor; AFCRL, ESSA, IDA, JPL, MIT, NASA Ames Research Center, NRL, Stanford Univ., Temple Univ., UCLA and Univs. of California, Chicago, Illinois, Iowa, Michigan and Minnesota, experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics/Convair, first stage contractor; Lockheed, second stage contractor.

Key Spacecraft Personnel		Affiliation
PM	W. E. Scull	NASA-GSFC
PS	G. H. Ludwig	NOAA-NESS
CO	J. P. Heppner	NASA-GSFC
CO	J. J. Quann	NASA-GSFC
CO	D. Stewart	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Solar Cosmic Rays	PI	K. A. Anderson	University of California, Berkeley
	OI	G. H. Pitt	University of California, Berkeley
Cosmic Ray Isotopic Abundance	PI	F. B. McDonald	NASA-GSFC
	OI	G. H. Ludwig	NOAA-NESS
Cosmic Ray Spectra and Fluxes	PI	J. A. Simpson	University of Chicago
	CO	G. Lentz	University of Chicago
	OI	C. Y. Fan	University of Arizona
	OI	P. Meyer	University of Chicago
Positron Search + Gamma Ray Spectrometers	PI	T. L. Cline	NASA-GSFC
	OI	F. W. Hones, Jr.	Los Alamos Science Laboratory
Electrostatic Analyzer	PI	J. H. Wolfe	NASA-ARC
Faraday Cup	PI	H. S. Bridge	Massachusetts Institute of Technology
	OI	A. M. Bonetti	Institute of Physics
	OI	B. Rossi	Massachusetts Institute of Technology
	OI	A. J. Lazarus	Massachusetts Institute of Technology
	OI	F. Scherb	University of Wisconsin
	OI	V. M. Vasyliunas	MPI-Aeronomy
Low Energy Proton Analyzer	PI	D. S. Evans	NOAA-ERL
	OI	L. R. Davis	NASA-GSFC
Low Energy Electron + Proton	PI	L. A. Frank	University of Iowa
	CO	H. Kiel	University of Iowa
	OI	J. A. Van Allen	University of Iowa
0.1-10 MEV Proton + Electron Scintillator	PI	A. Konradi	NASA-JSC
	OI	L. R. Davis	NASA-GSFC
	OI	R. A. Hoffman	NASA-GSFC
	OI	J. M. Williamson	NASA-GSFC
Rubidium + Fluxgate Magnetometer	PI	J. P. Heppner	NASA-GSFC
	OI	R. G. Ledley	NASA-GSFC
	OI	R. M. Campbell	Unknown
	OI	T. L. Skillman	NASA-GSFC
	OI	M. Sugiura	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Triax Search Coil Magnetometer	PI	E. J. Smith	NASA-JPL
	OI	R. E. Holzer	University of California, Los Angeles
Ion Mass Spectrometer	PI	H.A. Taylor	NASA-GSFC
	OI	H. Brinton	NASA-GSFC
	OI	R. Pickett	NASA-GSFC
RF Propagation	PI	R. B. Fritz	NOAA-ERL
	OI	J. K. Hargreaves	University of Lancaster
	OI	R. S. Lawrence	NOAA-ERL
	OI	O. K. Garriott	NASA-JSC
VLF Receiver	PI	R. A. Helliwell	Stanford University
	OI	L. H. Rorden	Devlco Incorporated
4-2 MHz Solar Bursts	PI	F. T. Haddock	University of Michigan
	CO	W. Potter	University of Michigan
Geophysical Lyman Alpha	PI	P. W. Mange	U.S. Naval Research Laboratory
Gegenschein Photometry	PI	C. L. Wolff	NASA-GSFC
	OI	K. L. Hallam	NASA-GSFC
	OI	S. P. Wyatt	University of Illinois
Interplanetary Dust Particles	PI	J. L. Rohn	Temple University
	OI	W. M. Alexander	Baylor University
Elec Spec 5 Channel 0.05-4 MeV	PI	J. R. Winckler	University of Minnesota
	OI	R. L. Arnoldy	University of New Hampshire
Ion Chamber (E*0.7 P*12 MeV)	PI	J. R. Winckler	University of Minnesota
	OI	R. L. Arnoldy	University of New Hampshire
Spherical Ret-Pot Analyzers	PI	R. C. Sagalyn	USAF Geophysical Laboratory
	OI	M. Smiddy	USAF Geophysical Laboratory
Planar Ion-Electron Trap	PI	E. C. Whipple	NOAA-ERL
	OI	B. E. Troy, Jr.	U.S. Naval Research Laboratory

PAGEOS I

Launch Vehicle – TAT-Agena D: first stage Thor augmented by three strap-on solid motors for total thrust of 333,275 pounds, 16,000-pound-thrust Agena D second stage. First stage employed inertial and radio guidance, second stage inertially guided. Height, 85 feet.

Spacecraft Description – Inflatable sphere with 100-foot diameter, based on Echo 1 design. Satellite made up of 84 panels of 0.0005-inch mylar coated on outside with vapor-deposited aluminum. At launch sphere was folded and packed in 28-inch spherical magnesium canister atop launch vehicle. Sphere weight, 125 pounds.

Project Objectives – By reflecting sunlight, Pageos provided an orbiting point source of light to be photographed over five-year period to determine location of continents, land masses, islands and other geographic points in relation to each other. International participation in ground-based observations, data acquisition and data analysis was encouraged.

Spacecraft Payload – Pageos I carried no instruments. Inflating compounds, about 10 pounds of benzoic acid and 20 pounds of anthraquinone, were dusted inside sphere prior to launch.

Project Results – Launched from Vandenberg AFB on June 24, 1966, the satellite's canister was injected into orbit of 2607 to 2662 miles at 87° inclination. Canister's two halves were separated and folded sphere then inflated in solar heat. Pageos was to be photographed by world-wide triangulation network of stations. Results were to pinpoint any location on earth, as measured from the center of mass, within 51 to 96 feet of its true position.

Major Participants – NASA Langley Research Center, spacecraft management; NASA Goddard Space Flight Center, tracking and data acquisition; G. T. Schjeldahl Co., spacecraft fabrication; Goodyear Aerospace, spacecraft canister and adapter; Environmental Science Services Administration and Army Corps of Engineers, camera network; NASA Lewis Research Center, launch vehicle management; Douglas, first stage contractor; Lockheed, second stage contractor.

Key Spacecraft Personnel	Affiliation
PM R. M. Rados	NASA-GSFC

Experiment	Experiment Personnel	Affiliation
Balloon Atmospheric Drag	PI E. J. Prior	NASA-LARC
Optical Observatory	PI L. W. Swanson	NOAA-NOS

EXPLORER XXXIII (IMP D)

Launch Vehicle – Thrust Agumented Delta (TAD), same as Intelsat IIA mission.

Spacecraft Description – Similar to Explorers XVIII, XXI and XXVIII, except that retrorocket was mounted atop spacecraft in place of usual magnetometer boom. Main body an octagon 28 inches across and 8 inches high. Four whip antennas projected from top and two 6-foot magnetometer booms and four solar panels extended from main body. Weight, 206 pounds.

Project Objectives – Fourth in series of seven IMPs, Explorer XXXIII was the first to attempt to orbit moon and was called AIMP – Anchored Interplanetary Monitoring Platform. Primary purpose was to study, at lunar distance, earth's magnetosphere and magnetic tail every 29½ days. Explorer XXXIII also was intended to measure interplanetary magnetic fields, solar wind and energetic particles in cis-lunar space. In addition, satellite was expected to provide data on lunar gravitational field and ionosphere.

Spacecraft Payload – Six scientific experiments included two flux-gate magnetometers, energetic particles experiment, electron and proton experiment, thermal ion and electron experiment and plasma probe. Four groups of n/p solar cells carried in radiation damage experiment. Spacecraft communication system included PFM-PM telemetry, 7-watt transmitter and digital data processor. Satellite spin stabilized, with 20 rpm design spin rate. Average power of 43 watts supplied by n/p solar cells and silver-cadmium batteries. Solid propellant retro motor intended to provide 916-pound-thrust for 20 to 22 seconds.

Project Results – Explorer XXXIII was launched July 1, 1966 from Cape Kennedy. Both second and third stages delivered more thrust than expected, although individually each was within specification. Total excess, 70 fps, was too much for retro motor to overcome for injection into lunar orbit, however, and instead motor was fired to drive Explorer XXXIII into earth orbit of 9880 to 270,560 miles at 29° inclination. All experiments were operating and useful data was acquired in alternate orbit.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, spacecraft prime contractor, experimenter; Westinghouse, spacecraft integration; Thiokol, retro motor, MIT, NASA Ames Research Center, Stanford Univ., UCLA and Univs. of California and Iowa, experimenters; Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	P. G. Marcotte	NASA-GSFC
PS	N. F. Ness	NASA-GSFC
CO	A. W. Schardt	NASA Headquarters
CO	J. J. Brahm	NASA-GSFC
CO	P. J. Heffner	NASA-GSFC
CO	J. Barsky	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Magnetometer	PI	N. F. Ness	NASA-GSFC
	OI	K. W. Behannon	NASA-GSFC
Retard. Poten. Anal. E+P	PI	G. P. Serbu	NASA-GSFC
	OI	E. J. Maier	NASA-GSFC
3 Axis Fluxgate Magnetometer	PI	C. P. Sonett	University of Arizona
	CO	D. S. Colburn	NASA-ARC
	OI	J. H. Wolfe	NASA-ARC
	OI	R. W. Silva	TRW Systems Group
	OI	W. J. Kerwin	NASA-ARC
Ion Chamber + Geiger Counter	PI	K. A. Anderson	University of California, Berkeley
Geiger Mueller Central + Solid State Detector	PI	J. A. Van Allen	University of Iowa
Faraday Cup	PI	H. S. Bridge	Massachusetts Institute of Technology
Solar Cell Damage	PI	L. W. Slifer, Jr.	NASA-GSFC
Lunar Ionospheric + Radio P.	PI	A. M. Peterson	Stanford University
	OI	B. B. Lusignan	Stanford University
	OI	V. R. Eshleman	Stanford University
	OI	O. K. Garriott	NASA-JSC
	OI	R. L. Leadabrand	SRI International
Selenodesy Experiment	PI	W. M. Kaula	University of California, Los Angeles

GEMINI X

Launch Vehicle – Modified Titan II: 430,000-pound-thrust first stage and 100,000-pound-thrust second stage; radio guided. Height, 109 feet.

Spacecraft Description – Conical vehicle consisted of two components: re-entry module with cabin, re-entry control and rendezvous and recovery sections, and adapter module with retrograde and equipment sections. Total spacecraft 18.4 feet long, 10 feet in diameter at base; re-entry module 11 feet long, 90 inches in diameter at base. Weight, 8295 pounds.

Project Objectives – Primary purpose was to conduct rendezvous and docking tests with Agena target vehicle. Secondary objectives included rendezvous with Gemini VIII's Agena target, two extravehicular activities (EVA) excursions and 15 scientific, technological and medical experiments.

Spacecraft Payload – Crew of command pilot John W. Young, 35, and pilot Michael Collins, 35. EVA life support system included 42-pound chest pack with 50-foot umbilical tether and hand-held maneuvering gun. Spacecraft systems included 100% oxygen environmental control system, two oxygen-hydrogen fuel cells, rendezvous radar system to provide range, range-rate and bearing angle data to on-board guidance computer, UHF/HF communication system, orbit attitude and maneuver system with 16 jets (thrust of 25, 85 and 100 pounds), re-entry control system with 16 25-pound-thrust engines, four solid propellant 2500-pound-thrust retrorockets and drogue and main parachutes. Bite-sized and rehydratable meals averaged 2600 calories per day.

Project Results – Gemini X's Agena target was launched July 18, 1966 from Cape Kennedy and injected into orbit of 183 to 190 miles at 28.9° inclination. Gemini X was launched 101 minutes later and placed in 100 to 168 mile orbit at a similar inclination. Large out-of-plane error, however, required use of about 60% of Gemini X's fuel supply to achieve rendezvous and docking with target vehicle on fourth revolution, vs. planned consumption of 28%, causing most of mission to be revised. A 14-second Agena burn raised Gemini X's apogee to 476 miles. First EVA initiated after a day in orbit as Collins stood on his seat to photograph selected stars and planets. EVA was terminated after about 55 minutes, however, when both astronauts' eyes became irritated. High oxygen flow rate was used to purge environmental control system. Next the crew rendezvoused, using onboard computing techniques and a minimum of fuel, with Gemini VIII Agena target vehicle. Collins then left spacecraft for his second EVA, retrieving a micrometeoroid detector from Agena although lack of handholds on target greatly increased task's difficulty; EVA was limited to 38 minutes due to shortage of fuel. Some data were obtained during mission from all but one secondary experiment. Gemini X re-entered after 43 revolutions, landing within three miles of intended impact point. Crew was recovered in good condition by U.S.S. Guadalcanal after flight of 70 hours, 47 minutes.

Major Participants – NASA Manned Spacecraft Center, spacecraft management; NASA Goddard Space Flight Center, tracking and data acquisition; McDonnell, spacecraft prime contractor; IBM and Honeywell, inertial guidance system; Westinghouse, rendezvous radar system; Rocketdyne, attitude and re-entry control systems; Garrett Corp., environmental control system; Collins Radio, communication system; Electro-Mechanical Research, telemetry system; General Electric, fuel cells; Thiokol, retrorockets; Northrop Ventura, recovery parachutes; TRW Systems Group, trajectory analysis; AF Space Systems Division, launch vehicles management; Martin, Titan II integration; General Dynamics/Convair, Atlas prime contractor; Lockheed, Agena prime contractor; U.S. Navy, recovery task force.

Key Spacecraft Personnel		Affiliation
MG	G. E. Mueller	NASA Headquarters
PM	W. C. Schneider	NASA Headquarters
PM	C. W. Mathews	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Zodiacal Light Photos	PI	E. Ney	Unknown
Synoptic Terrain Photos	PI	P. D. Lowman, Jr.	NASA-GSFC
Synoptic Weather Photos	PI	K. Nagler	National Meteorological Center
Micrometeorites	PI	C. L. Hemenway	Dudley Observatory
Micrometeorites	PI	C. L. Hemenway	Dudley Observatory
UV Star Field Camera	PI	K. G. Henize	NASA-JSC
	OI	L. R. Wackerling	Northwestern University
Ion Wake Measurement	PI	D. B. Medved	Electro-Opt Systems
Star Occultation Navigation	PI	E. Vallerie	USAF Avionics Laboratory
Tri-Axis Magnetometer	PI	W. D. Womack	NASA-JSC
Lunar UV Spec Reflect	PI	R. C. Stokes	NASA-JSC
Beta Spectrometer	PI	J. R. Marback	Lockheed Electronics
Cabin X-Ray Flux	PI	R. Lindsey	NASA-JSC
Landmark Measurement	PI	Unknown	Unknown
Positive Ion Sensing	PI	M. Smiddy	USAF Geophysical Laboratory
	OI	R. C. Sagalyn	USAF Geophysical Laboratory

LUNAR ORBITER I

Launch Vehicle – Atlas-Agena D: 390,000-pound-thrust Atlas D first stage, 160,000-pound-thrust Agena D second stage. First stage radio guided, second stage inertially guided. Height, 105 feet.

Spacecraft Description – Main body consisted of main equipment mounting deck and upper section supported by trusses and an arch, resembled truncated cone and was covered with aluminized mylar. Four solar panels extended from base, high-gain antenna dish mounted on 52-inch boom on one side, low-gain antenna mounted on 82-inch boom on opposite side and velocity control engine nozzle projected from top. In flight configuration, spacecraft was 12.2 feet across solar panels and 5.5 feet high. Weight, 853 pounds.

Project Objectives – The Orbiter program was to obtain topographic data in the lunar equatorial region – from 43°E to 56°W – to help select suitable landing areas for the Apollo LM. Five Lunar Orbiter missions, through the end of 1967, were to provide gravitation, micrometeoroid and radiation data. Lunar Orbiter I primary mission was to take high resolution photographs of various types of lunar surface – maria, highland areas and craters – nine locations to assess their suitability as landing sites for Apollo and Surveyor spacecraft. Secondary experiments included selenodesy studies and micrometeoroid and radiation measurements in cislunar and circumlunar space.

Spacecraft Payload – Both medium and high resolution lenses were included in 150-pound camera system. 80-mm medium resolution and 24-inch high resolution lens each employed aperture of f/5.6 and adjustable exposure speeds of 1/25, 1/50 and 1/100 second. Image motion compensation subsystem moved film platen slightly during exposure to eliminate blurring. Up to 194 dual exposure frames stored on 200-foot roll of film, then developed by damp monochemical process. Resulting 70-mm negative then scanned by high-intensity light beam and converted to video signal for transmission to earth at rate of 40 minutes per exposure. Mission events sequenced by digital programmer. A 10-watt transmitter and high-gain antenna were employed during video data transmission, otherwise a 0.5-watt transmitter and low-gain antenna were utilized. Spacecraft three-axis stabilized by eight nitrogen gas jets linked with five sun sensors for pitch and yaw reference, Canopus star tracker for roll reference and inertial reference unit for use when sun or Canopus not visible. Lunar Orbiter I's attitude was oriented to point camera system straight down (within ±0.2° of vertical) on each photographic pass. Bipropellant 100-pound-thrust velocity control engine employed for midcourse corrections and lunar orbit maneuvers. Passive temperature control system utilized multilayer thermal blanket of aluminized mylar and dacron plus special paint and insulation to control spacecraft temperatures in lunar orbit to within 35 to 85°F. About 375 watts of power supplied by 10,856 n/p solar cells and nickel-cadmium batteries.

Project Results – Lunar Orbiter I was launched August 10, 1966 from Cape Kennedy, placed in parking orbit and then injected into lunar trajectory. Midcourse correction was accomplished with 32-second burn 24.7 hours

after liftoff. Stray sunlight, apparently reflected from unexpected source on spacecraft into Canopus tracker, prevented sensor from locking on its star – until alternate acquisition methods were devised during third day of mission. After 92.1 hours of flight, Lunar Orbiter I's engine was fired for 9 minutes, 49 seconds to drop spacecraft into lunar orbit of 117 to 1159 miles at 12.2° inclination and period of 3 hours, 37 minutes. Series of 20 test photos of front and back sides of moon were made beginning August 18. These indicated blurring in high resolution photos, later attributed to spurious signals that tripped high resolution camera's shutter causing film to smear. Spacecraft's perilune was lowered to 35 miles August 21 and photography of the nine sites – spread over 3000-mile stretch of lunar equator – initiated following day. Perilune again was dropped August 25 to 25 miles. Lunar Orbiter I's medium resolution camera functioned normally and spacecraft was able to accomplish about 75% of its mission by August 29, when its final 32 exposures were made. In addition to valuable photography of potential landing sites and other areas of interest – more than two million square miles of moon's surface – Lunar Orbiter I took first two photos of earth from distance of the moon. Spacecraft maneuverability in lunar orbit proved to be a mission highlight. Spacecraft's nominal one-year lifetime was terminated prematurely October 29, as Lunar Orbiter I was crashed on far side of moon – at 6.7°N and 162°E – to avoid transmission interference with Lunar Orbiter II. Initial scientific results indicated radiation levels no higher than expected and gravitational properties pointing to pear-shaped moon, with pear's stem at lunar north pole. No micrometeoroid impacts were registered during Lunar Orbiter I's lifetime. Far side photographs showed fault area near center of back side, attributed to earthquake-like activity. Other photos revealed possible volcanic activity.

Major Participants – NASA Langley Research Center, spacecraft management, experimenter; Boeing, spacecraft prime contractor; Eastman Kodak, camera system, RCA, communication and power system; Jet Propulsion Laboratory, Deep Space Network management, experimenter; NASA Lewis Research Center, launch vehicle management; General Dynamics/Convair, first stage prime contractor; Lockheed, second stage, prime contractor.

Key Spacecraft Personnel		Affiliation
PM	I. G. Recant	NASA-LARC
CO	L. J. Kosofsky	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Lunar Photos	PI	L. J. Kosofsky	NASA Headquarters
	CO	I. G. Recant	NASA-LARC
Selenodesy	PI	W. H. Michael, Jr.	NASA-LARC
Meteoroid Detectors	PI	C. A. Gurtler	NASA-LARC
Radiation Measurements	PI	T. Foelsche	NASA-LARC

PIONEER VII

Launch Vehicle – Thrust Augmented Delta (TAD), same as Intelsat IIA mission.

Spacecraft Description – Cylinder 37 inches in diameter and 35 inches high. 52-inch mast containing high-gain and two low-gain antennas projected from one end and dual frequency antenna used in radio propagation experiment deployed from other end. Three 64-inch booms extended from mid-section, with magnetometer, wobble damper and orientation nozzle on ends of their respective booms. Spacecraft structure primarily aluminum; sides of cylinder covered with solar cells except for experiment view band at mid-section. Weight, 140 pounds.

Project Objectives – Second in series of interplanetary probes intended to provide data on solar wind, magnetic fields and cosmic rays. Designed to be placed in "out" solar orbit outside earth's orbit, Pioneer VII, together with Pioneer V inserted into "in" orbit in December 1965, was to gather data continuously from events on strip of solar surface extending nearly half way around sun.

Spacecraft Payload – Six experiments, virtually identical to Pioneer V's instrumentation, divided into three groups: plasma cup detector, quadrispherical plasma analyzer and radio propagation detector for solar wind studies; single axis fluxgate magnetometer for magnetic field data; and cosmic ray anistropy detector and cosmic ray telescope for cosmic ray measurements. Spacecraft systems included attitude control system, with nitrogen gas jet and four sun sensors to orient spin stabilized (60 rpm) probe normal to ecliptic plane. Experiments designed to sweep ecliptic plane; sun sensor defined direction of experiment sensors with respect to spacecraft/sun line. S-band communication system with redundant 8-watt TWTs used for transmissions at ranges in excess of 50 million miles. Transmission rates varied from 512 bits per second near earth to 8 bits per second at maximum range. Data storage capacity was 14,232 bits, about 19 hours of experiment and spacecraft data. Electronics mounted on circular platform in center of vehicle; thermal louvers below platform controlled internal temperatures. Power supplied by 10,368 n/p solar cells – 80 watts near earth and about 60 watts at 1.2 AU. Pioneer VII's design minimized and controlled magnetic fields due to spacecraft materials and currents to assure accurate measurements of low interplanetary magnetic fields.

Project Results – Launched August 17, 1966 from Cape Kennedy, Pioneer VII was successfully injected into planned solar orbit. At aphelion, to be reached February 8, 1967, probe was expected to be 104.6 million miles from sun; Pioneer VII's perihelion was 93 million miles. Spacecraft was inclined 0.097° to ecliptic plane and had period of 403 days. All scientific experiments were working as designed and returning good data.

Major Participants – NASA Ames Research Center, spacecraft management, experimenter; TRW Systems Group, spacecraft prime contractor; Jet Propulsion Laboratory, Deep Space Network management; Chicago Univ., Graduate Research Center of the Southwest, MIT and Stanford Univ., experimenters; NASA Goddard Space Flight Center, launch vehicle management, experimenter; Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	C. F. Hall	NASA-ARC
PS	J. H. Wolfe	NASA-ARC
CO	R. R. Nunamaker	NASA-ARC
CO	N. J. Martin	NASA-ARC
CO	N. A. Renzetti	NASA-JPL
CO	A. J. Siegmeth	NASA-JPL
MG	F. D. Kochendorfer	NASA Headquarters
SC	A. G. Opp	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Single Axis Magnetometer	PI	N. F. Ness	NASA-GSFC
Faraday Cup	PI	H. S. Bridge	Massachusetts Institute of Technology
Electrostatic Analyzer	PI	J. H. Wolff	NASA-ARC
	OI	R. W. Silva	TRW Systems Group
Two Frequency Beacon	PI	V. R. Eshleman	Stanford University
	OI	T. A. Croft	SRI International
Cosmic Ray Anisotropy	PI	K. G. McCracken	CSIRO
	OI	W. C. Bartley	National Academy of Sciences
	OI	U. R. Rao	ISRO Satellite Center
Cosmic Ray Telescope	PI	J. A. Simpson	University of Chicago
	OI	C. Y. Fan	University of Arizona
	CO	G. Lentz	University of Chicago
	OI	J. E. Lamport	University of Chicago
Celestial Mechanics	PI	J. D. Anderson	NASA-JPL
Superior Conj. Faraday	PI	G. S. Levy	NASA-JPL

GEMINI XI

Launch Vehicle – Titan II, same as Gemini X mission.

Spacecraft Description – Similar to Gemini X. Weight, 8374 pounds.

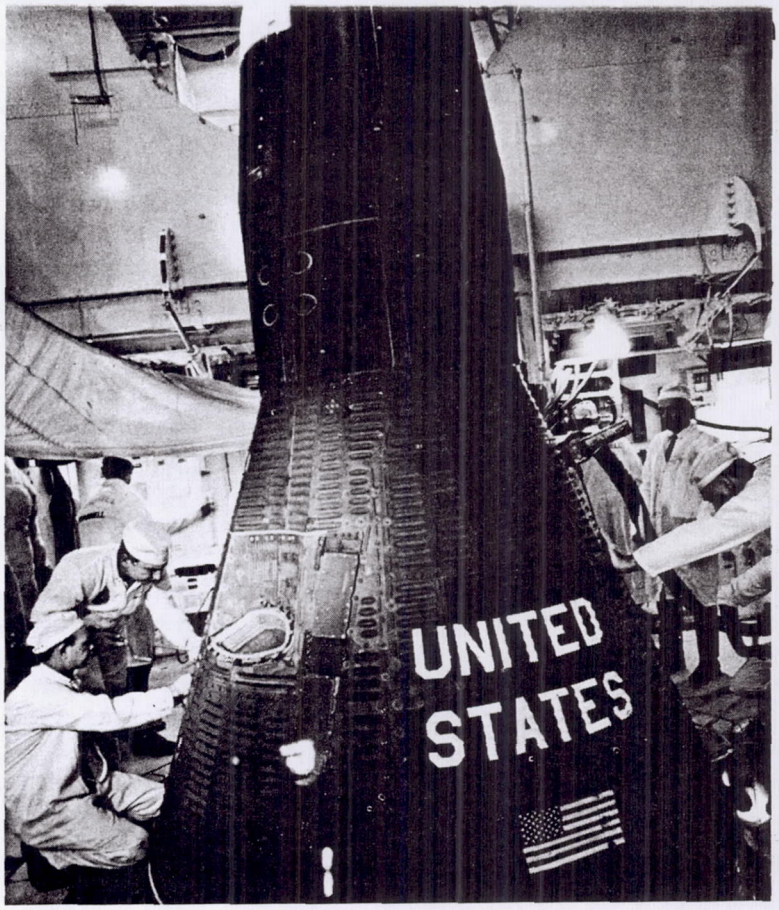
Project Objectives – Three-day mission intended to achieve rendezvous and docking with Agena target vehicle on first revolution, two EVA tests and spacecraft maneuvers to altitude of 865 miles. Stationkeeping tether exercise also scheduled, plus 12 scientific and technological experiments.

Spacecraft Payload – Crew of command pilot Charles Conrad, Jr., 35, and Richard F. Gordon, Jr., 35. Gordon's extravehicular activities (EVA) life support system included 42-pound chest pack with 30-foot umbilical and hand-held maneuvering gun fueled with nitrogen stored on adapter section. Spacecraft systems were similar to Gemini X.

Project Results – Atlas-Agena D launch from Cape Kennedy on September 12, 1966 placed target vehicle in planned 180 to 188 mile orbit at 28.9° inclination. Some 97 minutes later, Gemini XI lifted off enroute to orbit of 115 to 198 miles. Using on-board equipment exclusively, spacecraft rendezvoused and docked with Agena on first revolution – in record 94 minutes – and consumed less fuel than expected. Each astronaut then conducted two docking exercises with target vehicle. Umbilical EVA was conducted second day in orbit. Gordon found task of detaching one end of 100-foot tether from Agena and attaching it to spacecraft without proper restraints to be exhausting job. Workload overstressed life support system and Gordon perspired heavily, until sweat obscured his vision. EVA was aborted after 38 of scheduled 107 minutes. Next, Agena was fired for 26 seconds to raise spacecraft's apogee to record 850 miles – where radiation measurements were made along with spectacular earth photographs. After two revolutions, Agena again was ignited to lower spacecraft to its original apogee. Gordon's second EVA then was conducted – 129-minute stand up exercise with astronaut photographing star fields. Vehicles then were undocked and three-hour tether experiment carried out. By slowly rotating, vehicles were able to impart a very small gravitational force within Gemini XI. Final rendezvous conducted with use of on-board computer only, as rendezvous radar malfunctioned. Crew sighted and photographed Russia's Proton 3 during their flight. After 71 hours, 17 minutes and 44 revolutions, Gemini XI employed first closed loop, automatic re-entry mode and landed within three miles of planned impact point. U.S.S. Guam recovered the crew.

Major Participants – Same as Gemini X.

Gemini XI astronauts Charles "Pete" Conrad, Jr. and Richard F. Gordon, Jr. are sealed in their spacecraft prior to their 3-day flight beginning September 12, 1966. They rendezvoused and docked, conducted tethered spacecraft experiments, and made a successful, computer-controlled re-entry.



Key Spacecraft Personnel		Affiliation
MG	G. E. Mueller	NASA Headquarters
PM	W. C. Schneider	NASA Headquarters
PM	C. W. Mathews	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Nuclear Emulsion	PI	M. M. Shapiro	U.S. Naval Research Laboratory
Airglow Photos	PI	M. J. Koomen	U.S. Naval Research Laboratory
U.V. Star Field Camera	PI	K. G. Henize	NASA-JSC
	OI	L. R. Wackerling	Northwestern University
Ion Wake Measurement	PI	D. B. Medved	Electro-Opt Systems
Lunar U.V. Spectra Reflection	PI	R. C. Stokes	NASA-JSC
Synoptic Terrain Photos	PI	P. D. Lowman, Jr.	NASA-GSFC
Synoptic Weather Photos	PI	K. Nagler	National Meteorological Center
Dust Particles	PI	E. C. Morris	U.S. Geological Survey
Eff. on Blood Cell	PI	M. A. Bender	Holifield National Laboratory
Image Orthocon	PI	C. L. Hemenway	Dudley Observatory
	OI	E. Ney	Unknown

SURVEYOR II

Launch Vehicle – Atlas-Centaur; 390,000-pound-thrust Atlas D first stage, 30,000-pound-thrust Centaur second stage. First stage radio guided, second stage inertially guided. Height, 113 feet.

Spacecraft Description – Triangular frame of tubular aluminum supported vernier and retro propulsion systems, two thermal compartments, descent radar, two boom-mounted omnidirectional antennas, tripod landing gear with aluminum honeycomb foot pad on end of each leg and mast with planar antenna and solar panel mounted on top. Spacecraft 10 feet high, 14 feet across landings legs. Weight at launch, 2204 pounds; weight at lunar landing, 644 pounds.

Project Objectives – Second Surveyor mission to demonstrate lunar soft landing capability and to provide engineering and scientific data in support of Apollo program. Surveyor II was intended to approach moon at angle of 23° off vertical (vs. 6° for Surveyor I) and to land in Sinus Medii, maria in center of visible face of moon.

Spacecraft Payload – No significant changes from Surveyor I's payload. Survey television camera was focused on earth command from 4 feet to infinity with narrow- or wide-angle field of view and apertures from f/4 to f/22. Exposure time of 150 milliseconds could be extended by earth command. Camera pointed at mirror that could swivel 360°, tilt to reflect landing legs or above horizon. Produced 200- and 600-line photos and filter wheel provided clear or colored filters. Engineering instrumentation included temperature sensors, strain gauges and accelerometers. Spacecraft attitude and velocity control provided by sun acquisition sensor, sun and Canopus sensors, inertial reference unit, altitude marking radar, inertia burnout switch, radar altimeter and doppler velocity sensors, flight control electronics and six nitrogen gas jets. Propulsion system included three liquid variable-thrust (each 30 to 104 pounds) engines and solid propellant retrorocket with 8000 to 10,000 pounds of thrust. Communication system employed two low-gain antennas for 200-line photos, high-gain antenna for 600-line pictures and redundant 10-watt transmitters. Power supplied by 3960 p/n solar cells and silver-zinc batteries. Active temperature control provided for two thermal compartments, otherwise paint patterns, polished surfaces and insulation used for passive thermal control.

Project Results – Surveyor II was launched from Cape Kennedy on September 20, 1966 and placed in direct ascent trajectory to moon. Only two of three vernier engines fired for midcourse correction at 16.5 hours after liftoff, sending Surveyor II into tumbling mode from which it never recovered. Spacecraft crashed southeast of crater Copernicus after 62.8-hour flight.

Major Participants – Jet Propulsion Laboratory, spacecraft management, tracking; Hughes, spacecraft prime contractor; Ryan, radar altimeter and doppler velocity sensor; Thiokol, retro and vernier propulsion; NASA Lewis Research Center, launch vehicle management; General Dynamics/Convair, launch vehicle prime contractor.

ESSA III

Launch Vehicle – Thrust Augmented Delta (TAD), same as Intelsat IIA mission.

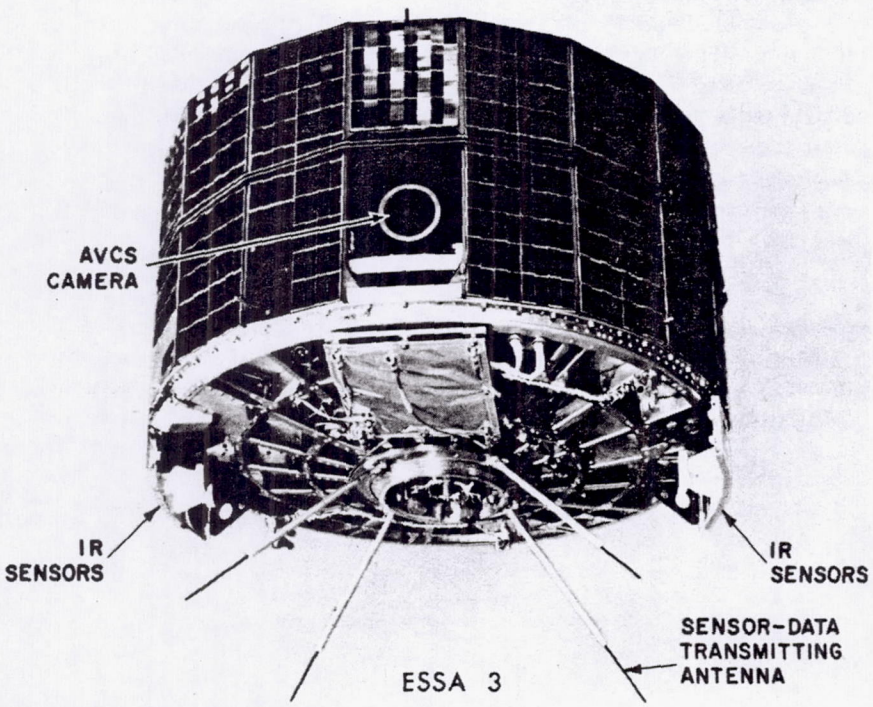
Spacecraft Description – Cylindrical 18-sided polygon 42 inches in diameter and 22 inches high. Two television cameras mounted 180° apart on sides, 18-inch receiving antenna mounted on top, solar cells covered top and sides and four whip antennas extended from baseplate. Weight, 320 pounds.

Project Objectives – Designed to provide daily global photographic coverage of weather systems for central processing and distribution by Weather Bureau's National Meteorological Center. ESSA III replaced ESSA I in Tiros Operational Satellite (TOS) system.

Spacecraft Payload – Television system utilized redundant 1-inch Advanced Vidicon Camera System (AVCS) vidicons, each mounted perpendicular to spin axis. Cameras designed to provide more than 150 photos daily of area 2000 miles on side, with resolution of two miles at center of each 800-line picture. Cameras programmed to take 6 or 12 photos per orbit, only when facing earth. Two tape recorders each stored up to 48 pictures for transmission to ground stations in Alaska and Virginia. ESSA III also carried solar and terrestrial radiation sensors – two identical radiometer arrays mounted on baseplate. Satellite spin rate of 10 rpm maintained by magnetic control system and solid propellant spinup motors. Magnetic coil, coupled with two infrared horizon sensors, also used for attitude control. Power supplied by 9100 n/p solar cells and nickel-cadmium batteries.

Project Results – ESSA III was launched October 2, 1966 from Vandenberg AFB – first Delta launch from West Coast – and injected into sun-synchronous orbit of 860 to 923 miles at 101° inclination. All satellite systems were working well and excellent cloud cover photos are being returned.

Major Participants – Environmental Science Services Administration, project management; NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; Douglas, launch vehicle prime contractor.



The Environmental Science Services Administration's ESSA III weather satellite. Sophisticated cameras and sensors provided valuable information about the world's weather patterns and conditions.

INTELSAT IIF-I

Launch Vehicle – Thrust Augmented Delta (TAD): Thor first stage with three strap-on solid propellant motors and total thrust of 333,500 pounds, 7800-pound-thrust second stage and 5750-pound-thrust solid propellant third stage. First and second stages radio guided, third stage spin stabilized. Height, 92 feet.

Spacecraft Description – Cylinder 56 inches in diameter and 26.5 inches high, with 18-inch antenna sleeve mounted on top and apogee motor nozzle and eight whip antennas extended from bottom. Aluminum honeycomb sides of cylinder were faced with solar cells and ends covered by thermal shields. Weight at launch, 357 pounds; weight in orbit, 192 pounds.

Project Objectives – The first Intelsat II communication satellite, nicknamed Lani (Hawaiian for "heavenly") Bird by press, was intended to be placed in synchronous equatorial orbit over Pacific at 175°E. Its microwave capability was to have been shared by NASA for support of the Apollo program, DOD's Defense Communication Agency and transpacific commercial traffic.

Spacecraft Payload – Intelsat IIF1's communication system was comprised of two redundant linear repeaters with 125 mc bandwidth and 6 db, and four 6-watt TWTs – up to three used at one time. System provided 240 two-way voice channels. Omnidirectional biconical horn array employed as transmitting antenna, with effective radiated power of 15 watts (vs. Early Bird's 6 watts). Telemetry subsystem utilized two encoders and two VHF transmitters. Spacecraft systems included hydrogen peroxide gas jets for spin stabilization and stationkeeping. Power supply of 85 watts furnished by 12,756 n/p solar cells and nickel-cadmium batteries. Intelsat IIF1 employed passive thermal control. Solid propellant apogee motor was intended to provide about 6000 fps to satellite for injection into synchronous orbit.

Project Results – Intelsat IIF1 was launched from Cape Kennedy on October 26, 1966 and placed in its initial transfer orbit. Apogee motor was fired four days later, but burned for 4.5 seconds instead of scheduled 17 seconds. As a result, Intelsat IIF1 was left in elliptical orbit of 2088 to 23,014 miles, with 12-hour period and inclination of 17°. Although commercial use of the satellite between ground stations in Hawaii, Japan, Australia and Brewster Flat, Washington was initiated December 3, this orbit prevented Intelsat IIF1 from fulfilling its NASA and DOD commitments.

Major Participants – Communications Satellite Corporation, spacecraft management; Hughes, spacecraft prime contractor; Aerojet-General, apogee motor; NASA Goddard Space Flight Center, launch vehicle management; Douglas, launch vehicle prime contractor.

LUNAR ORBITER II

Launch Vehicle – Atlas-Agena D, same as Lunar Orbiter I mission.

Spacecraft Description – Configuration unchanged from Lunar Orbiter I. Weight, 861 pounds.

Project Objectives – Lunar Orbiter II was intended to photograph 13 primary lunar landing areas, all but one in northern half of Apollo zone. Attempt to photograph Ranger VIII's impact point also was scheduled. Secondary experiments were devoted to selenodesy, micrometeoroids and radiation.

Spacecraft Payload – Three modifications were made to spacecraft as result of Lunar Orbiter I's mission. Camera system's shutter triggering circuits were changed to make them less sensitive to stray signals. To prevent undesirable reflections, outer end of low-gain antenna and edges and backs of solar panels were coated with black anti-reflective paint. And to overcome thermal control problems due to paint degradation, a new paint was applied to main deck and instrumented mirror and three metal coupons coated with different types of paint included in payload. Otherwise, Lunar Orbiter II duplicated its predecessor.

Project Results – Launched November 6, 1966, Lunar Orbiter II was placed in parking orbit and subsequently in lunar trajectory. 93.1 hours after liftoff spacecraft entered lunar orbit of 129 to 1147 miles at 11.8° inclination. After tracking probe for five days, Lunar Orbiter II's perilune was lowered to 31 miles. The 13 sites were photographed between November 19 and 25, using 184 frames of total capacity of 211 frames. Remaining frames were shot to move film through camera system at four to eight hour intervals to prevent development of a permanent set or sticking. These frames were used for back side coverage and for additional views of front side – including spectacular views of crater Copernicus. Some 205 frames were returned, but December 6 spacecraft suffered failure in its high-power transmission system and last six frames could not be transmitted. A 62-second burn was applied December 8 and Lunar Orbiter II's inclination changed to 17.5° to provide new data on lunar gravitational field and furnish flight operations experience at higher inclination. Lunar Orbiter II continued to provide scientific data and its photos were evaluated by Apollo site selectors. Lunar Orbiter II successfully photographed Ranger VIII's landing point and surface debris tossed out at impact. Photos also have given additional proof of lunar volcanic activity.

Major Participants – NASA Langley Research Center, spacecraft management, experimenter; Boeing, spacecraft prime contractor; Eastman Kodak, camera system, RCA, communication and power system; Jet Propulsion Laboratory, Deep Space Network management, experimenter; NASA Lewis Research Center, launch vehicle management; General Dynamics/Convair, first stage prime contractor; Lockheed, second stage, prime contractor.

Experiment	Experiment Personnel	Affiliation
Lunar Photos	PI L. J. Kosofsky	NASA Headquarters
Selenodesy	PI W. H. Michael, Jr.	NASA-LARC
Meteoroid Detector	PI C. A. Gurtler	NASA-LARC
Micrometeorites	PI C. L. Hemenway	Dudley Observatory
Radiation Measure	PI T. Foelsche	NASA-LARC

GEMINI XII

Launch Vehicle – Titan II, same as Gemini X mission.

Spacecraft Description – Similar to Gemini X. Weight, 8294 pounds.

Project Objectives – Last Gemini flight, Gemini XII was scheduled to perform rendezvous and docking with its target vehicle, several docking exercises, maneuvers utilizing target vehicle's propulsion system and three EVA tests. Tethered stationkeeping exercise and 14 scientific, technological and medical experiments also were planned.

Spacecraft Payload – Crew of command pilot James A. Lovell, Jr., 38 and Edwin E. Aldrin, Jr., 36. Life support for Aldrin's umbilical EVA supplied by 42-pound chest pack and 25-foot umbilical. Spacecraft systems similar to Gemini X.

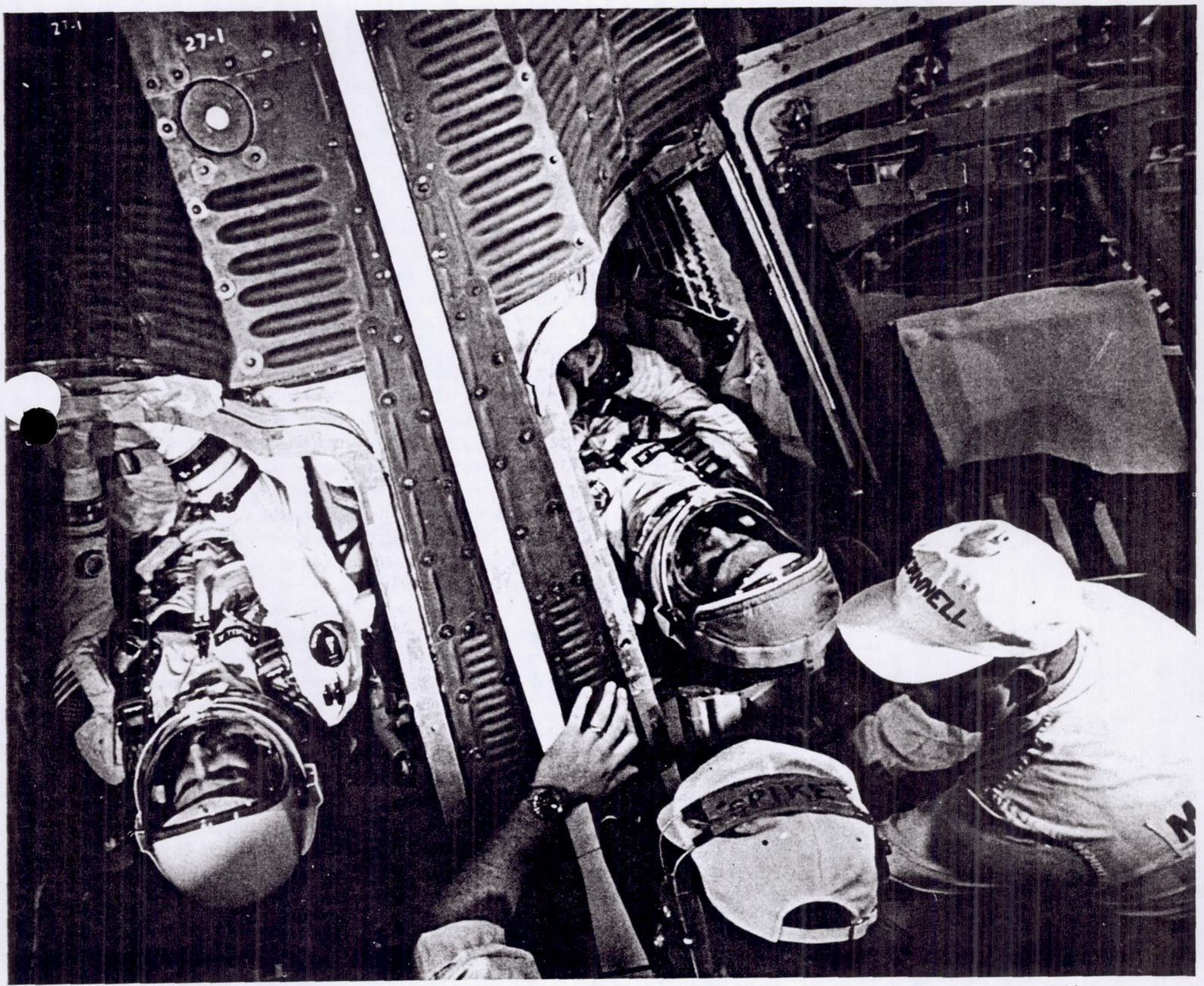
Project Results – Gemini XII's target vehicle was launched by an Atlas-Agena D from Cape Kennedy on November 11, 1966 and injected into orbit of 158 to 169 miles at 28.9° inclination. Gemini XII was launched 99 minutes later and placed in 100 to 168 mile orbit at similar inclination. Rendezvous and docking with Agena was completed on third revolution, although intermittent radar data required crew to rely heavily on visual sightings and on-board computer. Due to perturbation in initial firing of target vehicle's primary propulsion system, it was decided not to fire engine to raise spacecraft apogee to planned 530 miles. Instead, Agena's secondary propulsion system was used to maneuver spacecraft into position to photograph November 12 solar eclipse. Crew next performed three docking exercises with target vehicle. Initial standup EVA was accomplished during first day in orbit as Aldrin spent 2 hours, 29 minutes taking photographs and carrying out tasks preliminary to his umbilical EVA. Latter excursion came on second day and lasted 2 hours, 9 minutes. Aldrin first worked in hatch and nose area, then moved along handrail he had installed to adapter section where he utilized foot restraints and tethers to position himself in front of work panel mounted on rear of adapter. There he successfully carried out 17 relatively simple manual tasks. Finally, he moved to target vehicle adapter area and carried out another series of tasks, including use of Apollo torque wrench while again tethered. About a dozen 2-minute rest periods were scheduled during umbilical EVA. All tasks were completed and Aldrin was not physically overtaxed; his EVA was considered most successful to date. Gemini XII then was undocked and tether experiment carried out with target vehicle, with the two vehicles gravity gradient stabilized with relation to earth. Aldrin's second standup EVA lasted 59 minutes and included additional photography. Fuel cell and attitude control thruster problems again cropped up, but mission was successfully completed after 94 hours, 35 minutes and 59 revolutions as Gemini XII re-entered under automatic control and landed within three miles of intended impact point. Lovell and Aldrin were recovered in good condition by U.S.S. Wasp.

Major Participants – Same as Gemini X.

Key Spacecraft Personnel		Affiliation
MG	G. E. Mueller	NASA Headquarters
PM	W. C. Schneider	NASA Headquarters
PM	C. W. Mathews	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Frog Egg Growth	PI	Unknown	Unknown
Synoptic Terrain Photos	PI	P. D. Lowman, Jr.	NASA-GSFC
Synoptic Weather Photos	PI	K. Nagler	National Meteorological Center
Micrometeorites	PI	C. L. Hemenway	Dudley Observatory
Airglow Horizon Photos	PI	M. J. Koomen	U.S. Naval Research Laboratory
Micrometeorites	PI	C. L. Hemenway	Dudley Observatory
UV Star Field Camera	PI	K. G. Henize	NASA-JSC
	OI	L. R. Wackerling	Northwestern University
Earth Moon Photos	PI	E. C. Morris	U.S. Geological Survey
Sodium Cloud Photos	PI	J. E. Blamont	CNRS-SA
Tri-Axis Magnetometer	PI	W. D. Womack	NASA-JSC
Lunar UV Spectral Reflector	PI	R. C. Stokes	NASA-JSC
Beta Spectrometer	PI	J. R. Marback	Lockheed Electronics
Cabin X-Ray Flux	PI	Unknown	Unknown
Positive Ion Sensing	PI	M. Smiddy	USAF Geophysical Laboratory
	OI	R. C. Sagalyn	USAF Geophysical Laboratory
UV Pictures Solar	PI	R. Tousey	U.S. Naval Research Laboratory
	OI	L. Dunkelman	NASA-GSFC
	OI	C. L. Hemenway	Dudley Observatory
	OI	G. Newkirk, Jr.	High Altitude Observatory
	OI	E. Ney	University of Minnesota
	OI	F. Roach	National Bureau of Standards
Dust Particles	PI	C. L. Hemenway	Dudley Observatory
	OI	U. Shafrir	NASA-Goddard Institute for Space Studies

Sealing hatches on Lovell and Aldrin in Gemini XII spacecraft just before launch on November 11, 1966. During the 4-day earth orbital mission, the last in NASA's Gemini program, they rendezvoused and docked with the Agena.



1966

ATS I

Launch Vehicle – Atlas-Agena D: 390,000-pound-thrust Atlas D first stage and 16,000-pound-thrust Agena D second stage. First stage radio guided, second stage inertially guided. Height, 109 feet.

Spacecraft Description – Cylinder 56 inches in diameter, 57 inches high. Phased array experiment antenna and eight whip antennas extended from top, solar cells covered sides and eight VHF experiment antennas in phased array and apogee motor's nozzle projected from base of satellite. Weight prior to orbital insertion, 1550 pounds; weight in orbit, 775 pounds.

Project Objectives – ATS I was intended to perform a variety of experiments related to communication, meteorology and control technology, plus carry out scientific measurements of the orbital environment. In addition, its signals were to be used to study ionosphere's ion content.

Spacecraft Payload – Two communication experiments: two microwave repeaters for super high frequency (SHF) tests in three modes – multiple-access, frequency translation for color television, telegraph, digital and facsimile data relay and wideband data for transmitting TV pictures from meteorological experiment; and VHF repeater transmitting on 142.22 mc (via antenna with 9-db gain) and receiving on 135.6 mc for two-way voice communication between ground stations and specially equipped commercial aircraft. Two meteorological experiments: spin-scan cloud camera to produce a photo every 20 minutes – with horizontal scan generated by spacecraft spin and vertical scan provided by step motor – and capable, at synchronous altitude, of photographing 39% of earth; and relay of ESSA weather data (including ATS I's photos) in facsimile form to Automatic Picture Transmission (APT) ground stations in Australia, Japan and U.S. Three control experiments: 16-element electronically de-spun antenna to produce 10 times normal effective radiated power; nutation sensor to measure spin axis wobble to within 0.001° and damper to remove such wobble; and low thrust (0.00045 of a pound) resistojet engine for spin control and orbital maneuvers. Environmental measurement experiment package included seven experiments: suprathermal ion detector, magnetometer, omnidirectional electron-proton detector, electron magnetic deflection spectrometer, multi-element particle telescope, 30 solar cells to assess radiation damage and thermal coatings experiment. Spacecraft systems included 6250-pound-thrust apogee motor for injection into synchronous equatorial orbit. Satellite spin stabilized at 100 rpm, with two nitrogen gas jets for spinup and redundant hydrogen peroxide subsystems with two thrusters each for stationkeeping and attitude control. Telemetry system included four 2-watt transmitters, two for scientific experiment data and two for housekeeping data. Power supply, initially 185 watts, furnished by 23,870 n/p solar cells and nickel-cadmium batteries.

Project Results – ATS I was launched December 7, 1966 from Cape Kennedy

and placed in transfer orbit. At its second apogee, ATS I's injection motor was fired to produce near-circular orbit of 22,277 to 22,920 miles at inclination of 0.02°. Spacecraft then drifted west and was to be halted late in January over 151°W, east of Christmas Island. Early experiment results were outstanding. Spin-scan cloud camera was able to photograph Pacific Basin's changing weather pattern from dawn to dusk. Air-to-ground and air-to-air communication via satellite was demonstrated for first time. Spacecraft's de-spun antenna was properly phased and pointed toward earth. ATS I was designed for a three-year lifetime.

Major Participants – NASA Goddard Space Flight Center, spacecraft management, technology and scientific experimenter; Hughes, spacecraft prime contractor; JPL, apogee motor; Arinc, ESSA, FAA and Univ. of Wisconsin, technology experimenters; Aerospace Corp., BTL, Rice Univ., Stanford Univ., UCLA and Univ. of Minnesota, scientific experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics/ Convair, first stage prime contractor; Lockheed, second stage prime contractor.

Key Spacecraft Personnel		Affiliation
PM	R.J. Darcey	NASA-GSFC
PS	T.S. Aggson	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Biax Fluxgate Magnetometer	PI	P. J. Coleman, Jr.	University of California, La Jolla
Omni Solid State Particle Spectrometer	PI	G. A. Paulikas	Aerospace Corporation
	OI	J. B. Blake	Aerospace Corporation
	OI	S. C. Freden	NASA-GSFC
Elec. Spec 3 Ch., 0.05-0.15-0.5-1	PI	J. R. Winckler	University of Minnesota
Particle Telescope	PI	W. L. Brown	Bell Telephone Laboratories
	OI	L. J. Lanzerotti	Bell Telephone Laboratories
Solar Cell Radiation Damage	PI	R. C. Waddel	NASA-GSFC
Thermal Coating Degradation	PI	J. J. Triolo	NASA-GSFC
Range Rate Beacon	PI	Unknown	Unknown
Spin Scan Cloud Camera	PI	V. E. Suomi	University of Wisconsin
	OI	Ness Staff	NOAA-NESS
Communications Microwave Transponder	PI	Unknown	Unknown

Experiment	Experiment Personnel	Affiliation
Communications VHF Radio Transponder	PI Unknown	Unknown
Nutation Sensor	PI Unknown	Unknown
Resisto-Jet Thruster	PI Unknown	Unknown
Radio Beacon	PI A. V. Darosa	Stanford University
	OI P. C. Yuen	University of Hawaii
	OI T. H. Roelofs	University of Hawaii
Meteorological Data Relay System	PI S. Wishna	NASA-GSFC
	OI D. W. Holmes	NOAA-NESS
Suprathermal Ion Detector	PI J. W. Freeman	Rice University

BIOSATELLITE I

Launch Vehicle – First two stages of Thrust Augmented Delta (TAD): Thor first stage with three strap-on solid motors and total thrust of 328,000 pounds and 7800-pound-thrust second stage. Both stages radio guided. Height, 92 feet.

Spacecraft Description – Composed of adapter section and re-entry vehicle. Adapter section a cylinder-cone, 6 feet long and 40 to 57 inches in diameter. Re-entry vehicle a blunt cone with base 40 inches in diameter, included 280-pound aluminum blunt cone experiment capsule with 6 cubic feet of payload space. Total length, 81 inches; weight, 940 pounds.

Project Objectives – Intended to determine effects of space environment, particularly weightlessness, on life processes at three levels of organization: basic biochemistry of the cell; structure of growth of cells and tissues; and growth and form of entire plants and animals. Second objective was to compare effects of radiation on organisms in weightlessness and in earth's 1-g environment.

Spacecraft Description – Seven radiation experiments located in forward section of experiment capsule ahead of Strontium 85 gamma radiation source. Experiment specimens included bacteria, common bread mold, flowering plant, flour beetle, parasitic wasp and larvae and adult of common fruit fly. Shielded control versions of radiation experiments located in capsule's aft section, along with six general biology experiments including pepper plants, wheat seedlings, frog eggs and amoeba. Experiment life support systems provided oxygen-nitrogen atmosphere at sea level pressure, with capsule internal temperature maintained at 65 to 75°F. Adapter section insulation held spacecraft temperature between 0 and 100°F. Two telemetry systems with 2-watt transmitters, one located in adapter section for housekeeping data during mission and one in experiment capsule to return similar data after separation. Additional information stored by tape recorder in experiment capsule. Silver-zinc batteries provided power during flight, with smaller batteries used for retrofire and recovery operations. Ground commands and five on-board programmers employed to initiate spacecraft operations and re-entry events. Adapter section's attitude control system utilized gyros and six nitrogen gas jets to prevent spacecraft from rotating faster than about once in 20 minutes. Two infrared horizon scanners and magnetometer provided data for spacecraft alignment prior to re-entry. After separation, two cold gas jets used to spin up spacecraft to 57 rpm, 10,200-pound-thrust retrorocket ignited and vehicle despun by second pair of gas jets. Ablative heat shield designed to dissipate entry heating. Drogue parachute was to deploy at 80,000 feet and main parachute at 10,000 feet. USAF aircraft were to recover experiment capsule in air off Hawaii and take capsule to Hickam AFB for preliminary examination.

Project Results – Biosatellite I was launched from Cape Kennedy on December 14, 1966 and placed in orbit of 191 to 197 miles at 34° inclination.

All spacecraft systems and experiments apparently performed well during three-day mission. Re-entry vehicle separation was successfully achieved on 47th orbit, but retrorocket failed to fire leaving experiment capsule in orbit. As a result, no useful scientific data were obtained from Biosatellite I.

Major Participants – NASA Ames Research Center, spacecraft management, experimenter; General Electric, spacecraft prime contractor, experimenter; Thiokol, retrorocket; Bowling Green State Univ., Brookhaven National Laboratory, Colorado State Univ., Dartmouth College, Emory Univ., North American Aviation, NUS Corp., Oak Ridge National Laboratory, Rice Univ., and Univ. of California, experimenters; NASA Goddard Space Flight Center, launch vehicle management; Douglas, launch vehicle prime contractor.

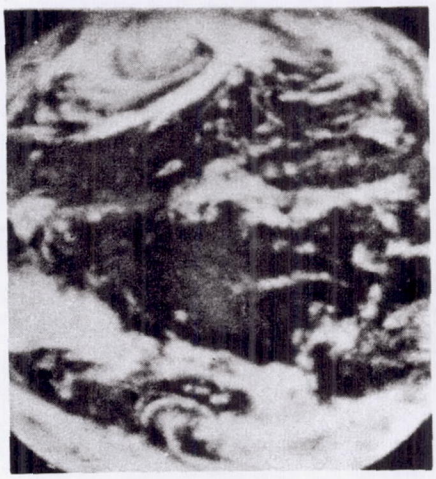
Experiment	Experiment Personnel	Affiliation
Weightlessness on Wheat Seedling	PI S. W. Gray	Emory University
	OI B. F. Edwards	Emory University
Growth Physiology of Wheat Seedling	PI C. J. Lyon	Dartmouth College
Biochemistry in Wheat Seedling	PI H. M. Conrad	Rocket Propulsion Corporation
	OI S. P. Johnson	North American Aviation
Effects on Egg of Rana Pipiens	PI R. S. Young	NASA Headquarters
	OI J. W. Tremor	NASA-ARC
Mutat. Respon. Habrobracon	PI R. C. Von Borstel	Oak Ridge National Laboratories
	OI R. I. Amy	Southwestern University
	OI R. S. Grosh	North Carolina State University
	OI R. H. Smith	Oak Ridge National Laboratories
	OI A. R. Whiting	Oak Ridge National Laboratories
Liminal Ang. of Plagiogeot.	PI S. P. Johnson	North American Aviation
	OI T. Tibbitts	University of Wisconsin
Effects on Tribolium Pupae	PI J. V. Slater	University of California, Berkeley
Effects on Drosophila Larvae	PI I. I. Oster	Bowling Green State University
Damage to Reproductive C.	PI E. Autenberg	Rice University
	OI L. Browning	Rice University

Experiment	Experiment Personnel		Affiliation
Genetic + Cytologic Studies	PI	A. H. Sparrow	Brookhaven National Laboratories
	OI	L. A. Schairer	Brookhaven National Laboratories
Com. Ef. Weigh/Rad. Ina/Mut D	PI	F. J. Deserres	Oak Ridge National Laboratories
	OI	B. B. Webber	Oak Ridge National Laboratories
Spc. + Rad. Eff. on Lysogenc B	PI	R. H. T. Mattoni	NUS Corporation
	OI	W.T. Ebersold	University of California, La Jolla
	OI	F. Eiserling	University of California, La Jolla
	OI	E. C. Keller, Jr.	NASA Headquarters
	OI	W. Romig	University of California, La Jolla
E. Weightlessness on Amoeba	PI	R. W. Price	Colorado State University
	OI	D. R. Ecksberg	General Electric Company

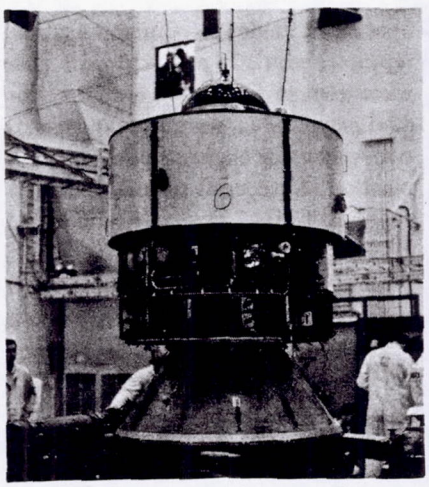
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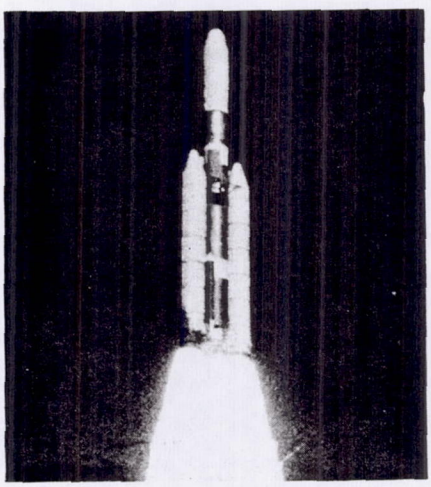
1967

1967 was a busy year for Applications Technology. Morning weather seen by ATS-I on January 24, 1967.

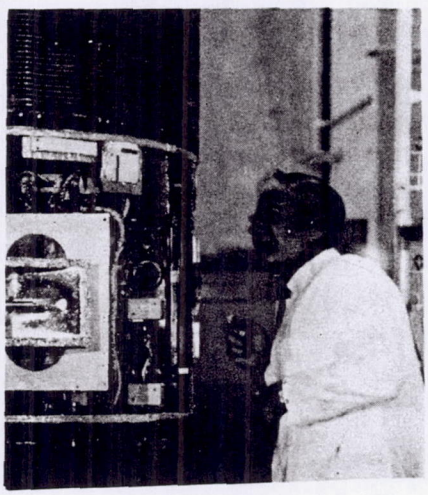


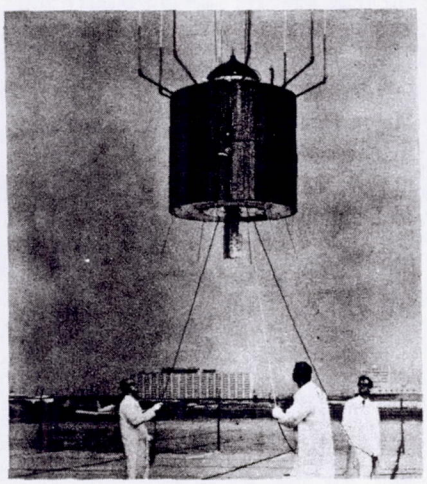
ATS-II checkout and launch on April 6, 1967.

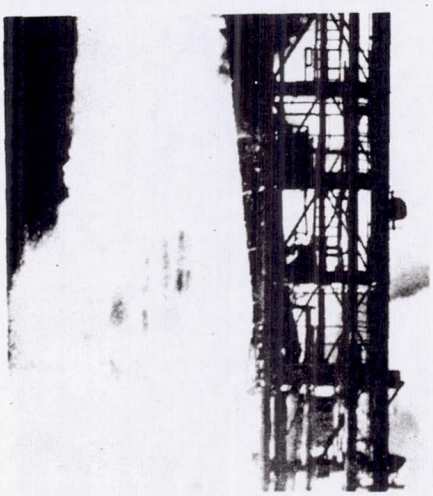




ATS-III assembly, checkout and launch.







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INTELSAT IIF2

Launch Vehicle – Thrust Augmented Delta (TAD): Thor first stage with three strap-on solid propellant motors and total thrust of 333,500 pounds, 7900-pound-thrust second stage and 6200-pound-thrust FW-4D solid propellant third stage. First and second stages radio guided, third stage spin stabilized. Height, 92 feet.

Spacecraft Description – Similar to Intelsat IIF1 with thermal shield added to protect exposed end of apogee motor. Cylinder 56 inches in diameter and 26.5 inches high with 18-inch communication antenna mounted on top and apogee motor nozzle and eight telemetry antennas extended from bottom. Aluminum honeycomb sides faced with solar cells and ends covered by thermal shields. Weight at launch, 357 pounds; weight in orbit, 192 pounds.

Project Objectives – Intended to provide 24-hour transpacific commercial communication service between ground stations in Australia, Japan, Hawaii, and Washington state. In addition, portion of Intelsat IIF2's capability leased to NASA for support of Apollo communication network and to DOD's Defense Communication Agency for military traffic between Hawaii and Philippines, Thailand and Japan. Expected mission lifetime, three years.

Spacecraft Payload – Communication system utilized two redundant linear repeaters with 125 mc bandwidth and 6 db, and four 6-watt TWTs – up to three used at one time. Omnidirectional biconical horn with effective radiated power of 15 watts employed as transmitting antenna. Provided 240 two-way voice channels plus teletype, television, data and facsimile communication. Spacecraft systems included hydrogen peroxide gas jets for spin stabilization and station-keeping. 85-watt power supply furnished by 12,756 n/p solar cells and nickel-cadmium batteries. Solid propellant apogee motor carried to impart about 6000 fps to Intelsat IIF2 for injection into synchronous orbit. Passive thermal control employed, plus 3-watt strip heater mounted at base of apogee motor nozzle.

Project Results – Intelsat IIF2 was launched from Cape Kennedy on January 11, 1967 and dog-legged into equatorial orbit, then its apogee motor fired to circularize orbit at synchronous altitude. The satellite was moved west and by February 4 reached its intended location at 178°W.

Major Participants – Communications Satellite Corporation, spacecraft management; Hughes, spacecraft prime contractor; Aerojet-General, apogee motor; NASA Goddard Space Flight Center, launch vehicle management; McDonnell Douglas, launch vehicle prime contractor.

ESSA IV

Launch Vehicle – Thrust Augmented Delta (TAD), except for third stage substitution of 5760-pound-thrust X-258 motor.

Spacecraft Description – Standard Tiros /ESSA configuration: cylindrical 18-sided polygon 42 inches in diameter and 22 inches high. Two television cameras mounted 180° apart on sides, 18-inch receiving antenna protruded from top, four telemetry antennas extended from top and bottom and sides covered by solar cells. Weight, 290 pounds.

Project Objectives – Satellite intended to replace ESSA II in Tiros Operational Satellite system. ESSA IV was equipped to provide daily coverage of local weather systems to some 180 worldwide automatic picture transmission (APT) receivers.

Spacecraft Payload – Camera system included two advanced 1-inch 800-line vidicons capable of photographing area 2000 miles on a side with two-mile resolution at picture center. Automatic picture transmission (APT) system designed to take and transmit a picture every 352 seconds. On-board triggering system programmed cameras to take pictures only when facing earth. Satellite spin stabilized at 10 rpm with magnetic attitude coils to position and maintain spin axis, and powered by 9100 n/p solar cells and nickel-cadmium batteries.

Project Results – ESSA IV was launched January 26, 1967 from Vandenberg AFB and inserted into retrograde, sun-synchronous orbit ranging from 822 to 894 miles at 102° inclination. Shutter malfunction the third day in orbit rendered one camera inoperative, but other camera was providing photography of global cloud cover.

Major Participants – Environmental Science Services Administration, project management; NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.

LUNAR ORBITER III

Launch Vehicle – Atlas-Agena D, same as ATS II mission.

Spacecraft Description – Identical to earlier Lunar Orbiters: truncated cone structure consisted of main equipment mounting deck and upper section supported by trusses and an arch. Main body covered by thermal blanket. Four solar panels, 36-inch parabolic high gain antenna and low gain antenna deployed from base and velocity control engine nozzle projected from top. In flight spacecraft 12.2 feet across solar panels and 5.5 feet high. Weight, 850 pounds.

Project Objectives – Mission primarily designed to photograph 12 promising Apollo and/or Surveyor landing sites that had been identified by screening Lunar Orbiter I and II photos. In addition, Lunar Orbiter III was to provide photography of broad scientific interest, furnish precision trajectory data to improve lunar gravitational field definition, measure circumlunar micrometeoroid flux and radiation dose and provide tracking target for Manned Space Flight Network.

Spacecraft Payload – Camera system weighed 150 pounds, including 80-mm medium resolution and 24-inch high resolution lenses. Each lens employed f/5.6 aperture and exposure speeds of 1/25, 1/50 and 1/100 second. Image motion compensation subsystem moved film platen slightly during exposure to eliminate blurring. Up to 194 dual exposure frames stored on 200-foot roll of film, then developed by damp monochemical process. 70-mm negative then scanned by high intensity light beam and converted to video signal for transmission in analog form at rate of 40 minutes per exposure. 10-watt transmitter and high gain antenna employed for video data transmission, otherwise 0.5-watt transmitter and low gain antenna used. Mission events sequenced by digital programmer. Spacecraft three-axis stabilized by eight nitrogen gas jets, with five sun sensors for pitch and yaw reference, Canopus star trackers for roll reference and inertial reference unit employed when sun or Canopus not visible. Attitude oriented to point camera system to within $\pm 0.2^\circ$ of vertical on each lunar photographic pass. Bipropellant 100-pound-thrust engine utilized for midcourse corrections and lunar orbit maneuvers. Passive thermal control system employed mylar-dacron thermal blanket plus insulation and special paints to maintain internal temperatures to within 35 to 85°F. About 375 watts of power supplied by 10,856 n/p solar cells and nickel-cadmium batteries.

Project Results – Lunar Orbiter III was launched February 5, 1967 from Cape Kennedy, placed in parking orbit and then inserted into lunar trajectory.

4.3-second midcourse correction applied 37.7 hours after liftoff. After 92.6 hours of flight, Lunar Orbiter III's engine was fired for 542.5 seconds to drop the spacecraft into orbit of 124 to 1150 miles around moon at 21° inclination. After four days in lunar orbit, spacecraft's perilune was lowered to about 30 miles and photographic portion of mission carried out from February 15 to 23. Total of 211 frames taken, and 182 returned until film advance motor burned out due to momentary electrical transient. Prime site photography returned included 10 potential Apollo sites plus Surveyor I's landing site, and permitted preliminary selection of eight Apollo sites. Lunar Orbiter III also returned coverage of additional 600,000 square miles of front and 250,000 square miles of back side for scientific purposes. Lunar Orbiter III's orbit was modified slightly April 12 to minimize time spent in darkness during April 24 lunar eclipse. Spacecraft provided gravitational field and lunar environment data and furnished target for Apollo ground stations.

Major Participants – NASA Langley Research Center, spacecraft management, experimenter; Boeing, spacecraft prime contractor; Eastman Kodak, camera system; RCA, communication and power systems; Marquardt, midcourse engine; Jet Propulsion Laboratory, Deep Space Network management, experimenter; NASA Lewis Research Center, launch vehicle management; General Dynamics, first stage prime contractor; Lockheed, second stage prime contractor.

Experiment	Experiment Personnel	Affiliation
Lunar Photos	PI L. J. Kosofsky	NASA Headquarters
	OI I. G. Recant	NASA-LARC
Selenodesy	PI W. H. Michael, Jr.	NASA-LARC
Meteoroid Detectors	PI C. A. Gurtler	NASA-LARC
Radiation Measurements	PI T. Foelsche	NASA-LARC

OSO III

Launch Vehicle – Delta: Thor first stage with 172,000 pounds of thrust, 7550-pound-thrust second stage and solid propellant 5700-pound-thrust third stage. First two stages radio guided, third stage spin stabilized. Height, 90 feet.

Spacecraft Description – Two sections: spinning base or "wheel" section and top or "sail" section. Nine-sided wheel section 44 inches in diameter and 9 inches high; three 30-inch arms extended from section with 6-inch sphere mounted on end of each arm. Sail section nearly simicircular with radius of 22 inches. Solar cells and solar pointing experiments mounted on side designed to face sun. Weight, 627 pounds.

Project Objectives – Repeat of OSO C which failed to orbit in August 1965. Nine experiments carried to study structure, dynamics and chemical composition of outer solar atmosphere through X-ray, visible and UV radiation measurements.

Spacecraft Payload – Experiment instrumentation totaled 252 pounds, included two sail-mounted pointing experiments – UV scanning monochromator and solar spectrometer and seven wheel spinning experiments – thermal radiation emissivity detector, six earth albedo telescopes, two direction radiometer telescopes, celestial gamma ray detector, solar X-ray detector, cosmic ray charge spectrum detector and solar X-ray telescope. Wheel section spin stabilized perpendicular to sun direction at 30 rpm by nitrogen gas jets. Sail section pointed at sun with accuracy of 1 minute of arc during sunlit portion of orbit by sun sensors, servo motors, nitrogen gas jets and magnetic torque coil. Communication system included improved command capability and data storage capability. Power supply of 26 watts furnished by 2016 n/p solar cells and nickel-cadmium batteries.

Project Results – OSO III was launched March 8, 1967 from Cape Kennedy and placed in orbit of 336 to 354 miles at 33° inclination. All experiments checked out and were returning useful data.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, experimenter; Ball Brothers Research Corp., spacecraft prime contractor; AF Cambridge Research Laboratories, MIT, NASA Ames Research Center and Univs. of California (San Diego), Michigan and Rochester, experimenters; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	J. M. Thole	NASA-GSFC
PS	S. P. Maran	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Celestial Gamma-Ray Detector	PI	G. W. Clark	Massachusetts Institute of Technology
	OI	W. L. Kraushaar	University of Wisconsin
	OI	G. P. Garmire	California Institute of Technology
Cosmic Ray Charge Spectrum	PI	M. F. Kaplon	University of Rochester
	OI	C. L. Deney	University of Rochester
	OI	B. R. Dennis	NASA-GSFC
Directional Radiometer	PI	C. B. Neel	NASA-ARC
	OI	R. N. Griffin	NASA-ARC
Earth Albedo Experiment	PI	C. B. Neel	NASA-ARC
	OI	G. G. Robinson	NASA-ARC
	CO	J. C. Arvesen	NASA-ARC
1-400A Solar Spectrometer	PI	W. M. Neupert	NASA-GSFC
	OI	W. A. White	NASA-GSFC
Solar X-Ray Detectors	PI	R. G. Teske	University of Michigan
Hard X-Ray Spectrometer	PI	L. E. Peterson	University of California, San Diego
Thermal Radiation Emissivity	PI	C. B. Neel, Jr.	NASA-ARC
Solar EUV, 260-1300A	PI	H. E. Hinteregger	USAF Geophysical Laboratory
	OI	L. A. Hall	USAF Geophysical Laboratory

INTELSAT IIF

Launch Vehicle – Thrust Augmented Delta (TAD).

Spacecraft Description – Intelsat IIF was similar to Intelsat IIF2.

Project Objectives – Completed Intelsat II communication system and augmented Early Bird's transatlantic capability. Also will be used in Apollo communication network.

Spacecraft Payload – Communication system utilized two redundant linear repeaters with 125 mc bandwidth and 6 db, and four 6-watt TWTs – up to three used at one time. Omnidirectional biconical horn with effective radiated power of 15 watts employed as transmitting antenna. Provided 240 two-way voice channels plus teletype, television, data and facsimile communication. Spacecraft systems included hydrogen peroxide gas jets for spin stabilization and station-keeping. 85-watt power supply furnished by 12,756 n/p solar cells and nickel-cadmium batteries. Solid propellant apogee motor carried to impart about 6000 fps to Intelsat IIF2 for injection into synchronous orbit. Passive thermal control employed, plus 3-watt strip heater mounted at base of apogee motor nozzle.

Project Results – Intelsat IIF was launched from Cape Kennedy on March 23, 1967 and successfully placed in equatorial orbit above Atlantic where, three days later, its apogee motor was fired to circularize orbit at altitude of 22,300 miles. Commercial service initiated April 7, 1967.

Major Participants – Communications Satellite Corporation, spacecraft management; Hughes, spacecraft prime contractor; Aerojet-General, apogee motor; NASA Goddard Space Flight Center, launch vehicle management; McDonnell Douglas, launch vehicle prime contractor.

ATS II

Launch Vehicle – Atlas-Agena D: 390,000-pound-thrust Atlas SLV-3 first stage and 16,000-pound-thrust Agena D second stage. First stage radio guided, second stage inertially guided. Height, 109 feet.

Spacecraft Payload – Cylinder 56 inches in diameter and 72 inches high. Two pairs of 123-foot gravity gradient primary stabilization booms and pair of 45-foot damping booms deployed from midsection, eight command and telemetry antennas extended from top and four communication experiment antennas projected from bottom. Solar cells covered sides except for mid-section experiment band. Weight, 815 pounds.

Project Objectives – Primary mission was to test a gravity gradient control system in 6900 mile orbit. In addition, microwave communication experiment, two meteorological cameras, eight scientific experiments and Department of Defense albedo experiment were carried.

Spacecraft Payload – Gravity gradient system consisted of four primary beryllium-copper booms in X configuration with electric motors to extend and retract or scissor (from 11° to 31° off local vertical) the booms, damper booms designed to maintain stabilization within 3° in all three axes and combination passive damper with competing eddy current and hysteresis dampers. Other gravity gradient subsystems included two 525-line television cameras to measure boom thermal bending characteristics, power control unit and attitude sensor system composed of digital solar aspect sensor, two IR earth sensors and spacecraft's polarized communication antenna. Two microwave repeaters made up SHF communication system for multiple access and frequency translation tests. Two 1-inch 800-line advanced vidicon cameras, one narrow angle and one wide angle, and a tape recorder were carried in meteorological experiment. Eight experiments made up environmental measurements experiment package: omnidirectional proton-electron counters, electron magnetic deflection spectrometer, multi-element particle telescope, VLF whistler mode detector, cosmic radio noise receiver, solar cell radiation damage array, thermal coating samples and electric field experiment. Spacecraft systems included four 2-watt VHF telemetry transmitters and 22,000 n/p solar cells and nickel-cadmium batteries to furnish initial power of 185 watts. Pair of subliming jets using solid ammonia salt as propellant carried to invert ATS II in orbit up to 10 times.

Project Results – Launched April 6, 1967 from Cape Kennedy, ATS II failed to reach its intended circular orbit as the second stage failed to restart. As a result, satellite remained in orbit of 115 to 6947 miles at 28° inclination.

Although stabilization booms were successfully deployed, ATS I's gravity gradient control system could not be properly tested in elliptical orbit. Limited data were obtained from almost all of the other experiments.

Major Participants – NASA Goddard Space Flight Center, spacecraft management, experimenter; Hughes, spacecraft prime contractor; GE, gravity gradient control system; deHavilland, stabilization booms; TRW, hysteresis damper; RCA, meteorological camera system; Bell Telephone Laboratories and Univs. of California (San Diego) and Minnesota, experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics, first stage prime contractor; Lockheed, second stage prime contractor.

Key Spacecraft Personnel		Affiliation
PM	R.J. Darcey	NASA-GSFC
PS	T.S. Aggson	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Radio Astronomy 7 Step 5-3MC	PI	R. G. Stone	NASA-GSFC
Magnetospheric Electricity Fields	PI	T. L. Aggson	NASA-GSFC
Elec. Spec. 3 Ch., .05-.15-.5-1	PI	J. R. Winckler	University of Minnesota
Particle Telescope	PI	W. L. Brown	Bell Telephone Laboratories
Omni Proton-Electron Detectors	PI	C. E. McIlwain	University of California, San Diego
	OI	R. W. Fillius	University of California, San Diego
VLF Receivers, 5-45	PI	W. L. Brown	Bell Telephone Laboratories
Earths Albedo	PI	Unknown	Unknown
Communications Microwave Transponder	PI	Unknown	Unknown
Gravity Grad. Stabilization	PI	Unknown	Unknown
Vidicon Camera System (AVCS)	PI	H. Ostrow	NASA-GSFC
Thermal Coating Degradation	PI	J. J. Triolo	NASA-GSFC
Solar Cell Degradation	PI	R. C. Waddel	NASA-GSFC

SURVEYOR III

Launch Vehicle – Atlas-Centaur: 390,000-pound-thrust Atlas D first stage, 30,000-pound-thrust Centaur second stage. First stage radio guided, second stage inertially guided. Height, 113 feet.

Spacecraft Description – Triangular aluminum frame supported vernier and retro propulsion systems, two thermal compartments, television and surface sampler experiments, descent radar, two boom-mounted omnidirectional antennas, tripod landing gear with aluminum honeycomb foot pads and mast with planar antenna and solar panel mounted on top. Spacecraft 10 feet high, 14 feet across landing legs. Weight at launch, 2283 pounds; landing weight, 625 pounds.

Project Objectives – To further develop lunar soft landing technology and to provide scientific and engineering data in support of Apollo program. Intended landing area was 37-mile diameter circle in eastern Oceanus Procellarum.

Spacecraft Payload – Major change from earlier Surveyors was addition of surface sampler experiment, a scoop mounted on flexible motor-driven arm able to range over area of 24 square feet. Survey television camera was focused on earth command from 4 feet to infinity with narrow or wide angle field of view and apertures from f/4 to f/22. Exposure time of 150 milliseconds extended by earth command. Camera pointed at mirror that swiveled 360°, or at two new fixed mirrors. Produced 200- and 600-line photos and filter wheel provided clear, red, green or blue filters. Instrumentation included temperature sensors, strain gauges and accelerometers. Spacecraft velocity and attitude control provided by sun acquisition sensor, sun and Canopus sensors, inertial reference unit, altitude marking radar, inertial burnout switch, radar altimeter and doppler velocity sensor, flight control electronics and six nitrogen gas jets. Propulsion system utilized three variable-thrust (each 30 to 104 pounds) engines and solid propellant retrorocket with 8000 to 10,000 pounds of thrust. Communication system employed two low gain antennas for 200-line photos, high gain antenna for 600-line photos and redundant 10-watt transmitters. Power supplied by 3960 n/p solar cells and silver-zinc batteries. Active thermal control provided for thermal compartments, otherwise passive techniques such as paint patterns, polished surfaces and insulation employed.

Project Results – Surveyor III was launched April 17, 1967 from Cape Kennedy and, for first time in Surveyor program, placed in parking orbit prior to injection into lunar trajectory. 4.3-second midcourse correction

accomplished 21.9 hours after liftoff. Surveyor III approached moon at 25° angle, landing after 65.0 hours of flight. High reflective rocks apparently confused spacecraft's descent radar, causing vernier engines to continue firing at landing rather than cut off at altitude of 14 feet. As a result, Surveyor III bounced twice, to height of 35 feet and then to 11 feet, before engines shut off and spacecraft settled in upright position on 14° slope of a shallow crater at 2.4°S, 23.3°W – within 1.7 miles of intended landing area. Initial 200-line photos were received within an hour after landing. Two days later surface sampler was exercised for first time, then proceeded through full schedule of pressing, digging into, trenching to depth of 7 inches, scooping up and depositing – with accuracy of ½ inch – surface material in view of survey camera. Sample was photographed through each of camera's four filters, and pictures then combined on earth to produce color picture, with material appearing to be dark gray. Lunar bearing strength averaged about 4 psi in Surveyor III's vicinity; surface material was characterized as similar to damp, fine-grained soil or wet, hard-packed sand on earth. Some 6300 photographs returned, including pictures of earth during April 24 lunar eclipse when moon's surface temperature dropped to -155°F. Surveyor III was shut down for lunar night May 3 and failed to come back to life following two-week cold soak. Overall, Surveyor III's results correlated well with data returned by Surveyor I.

Major Participants – Jet Propulsion Laboratory, spacecraft management, tracking; Hughes, spacecraft prime contractor; Ryan, radar altimeter and doppler velocity sensor; Thiokol, retro and vernier propulsion; Cal Tech and U.S. Geological Survey, experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM H. H. Haglund		NASA-JPL
PS L. D. Jaffe		NASA-JPL
Experiment	**Experiment Personnel**	**Affiliation**
Television Experiment	PI E. M. Shoemaker	California Institute of Technology
	OI R. M. Batson	U.S. Geological Survey
Surface Sampler-Photophysical	PI E. M. Shoemaker	California Institute of Technology
	OI R. F. Scott	California Institute of Technology

ESSA V

Launch Vehicle – Thrust Augmented Delta, same as ESSA IV mission.

Spacecraft Description – Configuration identical to ESSA IV. Weight, 320 pounds.

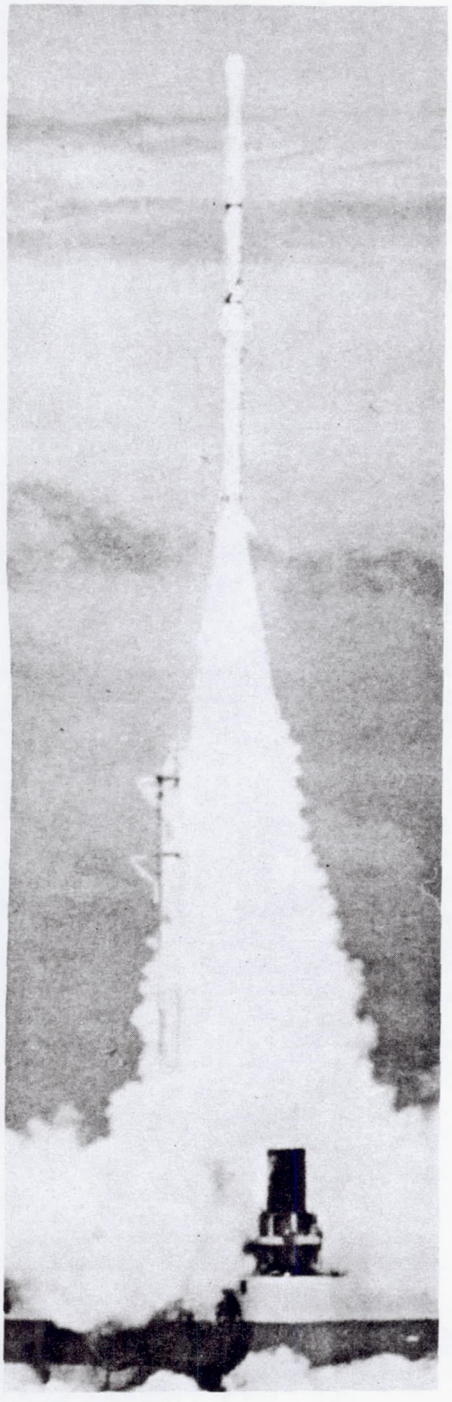
Project Objectives – Replaced ESSA III in Tiros Operational Satellite system. ESSA V was intended to furnish daily global coverage of weather systems for central processing and distribution.

Spacecraft Payload – Camera system featured two redundant 1-inch 800-line advanced vidicon camera system (AVCS) vidicons. Dual tape recorders carried, each capable of storing up to 48 frames for transmission to ground stations in Alaska and Virginia. Area covered in each picture comparable to ESSA IV's capability. Cameras programmed to take either 6 or 12 photos per orbit. Radiation sensors included to measure global distribution of solar radiation reflected by earth and its atmosphere and long wave radiant energy emitted by earth. Satellite spin stabilized at 9.2 rpm. Other spacecraft systems similar to ESSA IV.

Project Results – ESSA V was launched from Vandenberg AFB on April 20, 1967 and placed in orbit of 840 to 883 miles at 102° inclination. Camera and spacecraft checkout was completed May 8 with good results. Satellite provided good quality pictures for processing and distribution by the National Meteorological Center.

Major Participants – Environmental Science Services Administration, project management; NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.

SAN MARCO II



Launch Vehicle – Solid propellant Scout.

Spacecraft Description – Sphere 26 inches in diameter with 100-inch ionospheric experiment antennas extended from top and bottom and four telemetry antennas mounted around equator. Weight, 285 pounds.

Project Objectives – First satellite launch attempt from mobile sea-based platform. Intended to make continuous equatorial air density measurements, plus obtain data on ionospheric characteristics – electron content, electron density irregularities and guided propagation phenomena.

Spacecraft Description – Spacecraft structure utilized in air density experiment: inner structure consisted of cylindrical center post and central drum, connected by three orthogonal strain gauge elements to thin-walled aluminum outer structure. Air density balance mechanism, housed in center post, was protected during launch by pneumatic caging system. 0.6-watt HF transmitter served as ionospheric experiment. Ground-activated programmer controlled air density experiment and telemetry transmissions; balance system sensitivity modified by ground command. PAM/FM/PM telemetry system employed redundant transmitters. Six solar cells on outer shell provided rough attitude data. Power supplied by mercury batteries. Spin stabilized at less than 6 rpm. Passive thermal control provided by paint pattern.

Project Results – San Marco II was launched by an Italian crew April 26, 1967 from 90 x 300 foot platform anchored in Formosa Bay, three miles off coast of Kenya at 2.56°S. Launch operations conducted from smaller plat-

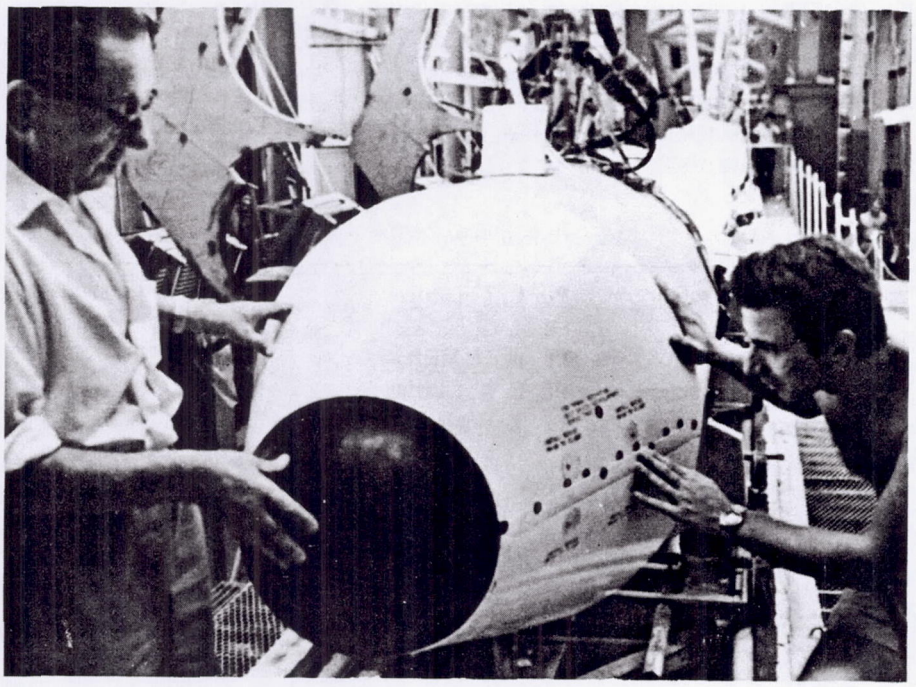
The San Marco II was launched from a platform in the Indian Ocean.

form 500 yards away which also housed primary telemetry station. Initial orbit of 135 to 498 miles at 2.9° inclination was close to nominal and permitted successful operation of both experiments.

Major Participants – Italian Commission for Space Research (CRS), spacecraft management; Univ. of Rome Aerospace Research Center, spacecraft prime contractor, experimenter; Univ. of Florence, experimenter; NASA Langley Research Center, launch vehicle management; LTV, launch vehicle prime contractor; NASA Goddard Space Flight Center, tracking and data acquisition.

Key Spacecraft Personnel		Affiliation
PM	A. J. Caporale	NASA-GSFC
PM	L. Broglio	National Research Council of Italy
PS	L. Broglio	National Research Council of Italy
SC	R. F. Fellows	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Radio Beacon	PI	L. Broglio	National Research Council of Italy
Air Density Experiment	PI	L. Broglio	National Research Council of Italy
20 MC Beacon	PI	N. Carrara	University of Florence



Preparing to launch San Marco II, Italy's space mission.

LUNAR ORBITER IV

Launch Vehicle – Atlas-Agena D, same as ATS 2 mission.

Spacecraft Description – Identical to Lunar Orbiter III. Weight, 860 pounds.

Project Objectives – With the Lunar Orbiter program's primary purpose of photographing potential Apollo and Surveyor landing sites completed, Lunar Orbiter IV's mission was designed as a photographic survey of lunar surface features for scientific purposes. Previous gravitation field, micrometeoroid and radiation experiments also were included.

Spacecraft Payload – Similar to Lunar Orbiter III.

Project Results – Launched May 4, 1967 from Cape Kennedy, Lunar Orbiter IV was ejected from parking orbit into lunar trajectory. Midcourse correction of 52.7 seconds was applied after 18.3 hours of flight followed by deboost burn of 501.7 seconds to insert spacecraft into lunar orbit of 1681 to 3750 miles at 85° inclination, 88.7 hours after liftoff. Photography sequence was initiated May 5 and continued until May 27. Initial thermal and film fogging problems were overcome by modifying operating procedures. Final readout of Lunar Orbiter 4's 163 frames – covering 99% of moon's front side and additional back side areas – was completed June 2. Orbit then was lowered to match Lunar Orbiter V's intended orbit to provide tracking and gravitational field data in support of that mission.

Major Participants – NASA Langley Research Center, spacecraft management, experimenter; Boeing, spacecraft prime contractor; Eastman Kodak, camera system; RCA, communication and power systems; Marquardt, midcourse engine; Jet Propulsion Laboratory, Deep Space Network management, experimenter; NASA Lewis Research Center, launch vehicle management; General Dynamics, first stage prime contractor; Lockheed, second stage prime contractor.

Experiment	Experiment Personnel	Affiliation
Lunar Photography	PI L. J. Kosofsky	NASA Headquarters
	OI I. G. Pecant	NASA-LARC
Selenodesy	PI W. H. Michael, Jr.	NASA-LARC
Meteoroid Detectors	PI C. A. Gurtler	NASA-LARC
Radiation Measurement	PI T. Foelsche	NASA-LARC

ARIEL III (UK III)

Launch Vehicle – Solid propellant Scout: 101,000-pound-thrust Algol IIB first stage, 61,000-pound-thrust Castor II second stage, 21,000-pound-thrust Antares II third stage and 5750-pound-thrust FW-4S fourth stage. First three stages inertially guided, fourth stage spin stabilized. Height, 72 feet.

Spacecraft Description – Cylinder 30 inches in diameter and 3 feet high. Two experiment loop antennas and four telemetry antennas mounted on top and four solar panels supporting two additional experiment loop antennas deployed from baseplate. Solar cells covered sides. Weight, 198 pounds.

Project Objectives – Third satellite in U.S.-U.K. cooperative space program, and first built by U.K. Intended to extend atmospheric and ionospheric investigations conducted by Ariel I and II. Mission lifetime, expected one year.

Spacecraft Payload – Five experiments: molecular oxygen, electron density and temperature, terrestrial radio noise, VLF radiation and galactic radio noise. Spacecraft spin stabilized at 30 rpm. Communication system included PFM/PM telemetry with 0.25-watt transmitter and data storage capability. Power supplied by 7008 n/p solar cells and nickel-cadmium batteries. Passive thermal control employed.

Project Results – Ariel III was launched from Vandenberg AFB on May 5, 1967 and placed in orbit of 306 to 373 miles at 80° inclination. All experiments were operating normally.

Major Participants – U.K. Science Research Council, project management; Royal Aircraft Establishment, project technical direction; British Aircraft Corp., spacecraft prime contractor; GEC Electronics, electronic systems; Meteorological Office, Radio and Space Research Station and Univs. of Birmingham, Manchester and Sheffield, experimenters; NASA Langley Research Center, launch vehicle management; LTV, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	A. C. Ladd	Science Research Council
PS	H. Massey	University College of London
CO	J. Smith	Unknown
PM	R. C. Baumann	NASA-GSFC
PS	S. J. Bauer	NASA-GSFC
CO	R. K. Browning	NASA-GSFC
SC	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
Langmuir Probe	PI	J. Sayers	University of Birmingham
Radio Astronomy, 2.0-4.3 MHz	PI	F. G. Smith	University of Cambridge
Molecular Oxygen	PI	K. H. Stewart	Meteorological Office
	PG	T. L. Van Raalte	Weapons Research Establishment
HF Thunderstorm Noise	PI	J. A. Murphy	Unknown
VLF FF Receivers	PI	T. R. Kaiser	University of Sheffield
	OI	A. R. W. Hughes	University of Natal
	OI	K. Bullough	University of Sheffield
RF Capacitance Probe	PI	J. Sayers	University of Birmingham

EXPLORER XXXIV (IMP F)

Launch Vehicle – Thrust Augmented Delta (TAD).

Spacecraft Description – Improved version of Explorers XVIII, XXI and XXVIII. Main body an octagon 28 inches across and 10 inches high. Two 6-foot magnetometer booms and four solar panels extended from midsection and four telemetry antennas projected from top. Weight, 163 pounds.

Project Objectives – Fifth in seven-satellite IMP series intended to study sun-earth relationships. Explorer XXXIV carried 11 experiments to measure solar and galactic cosmic rays within and at boundary of magnetosphere and in interplanetary space. Mission lifetime, one year.

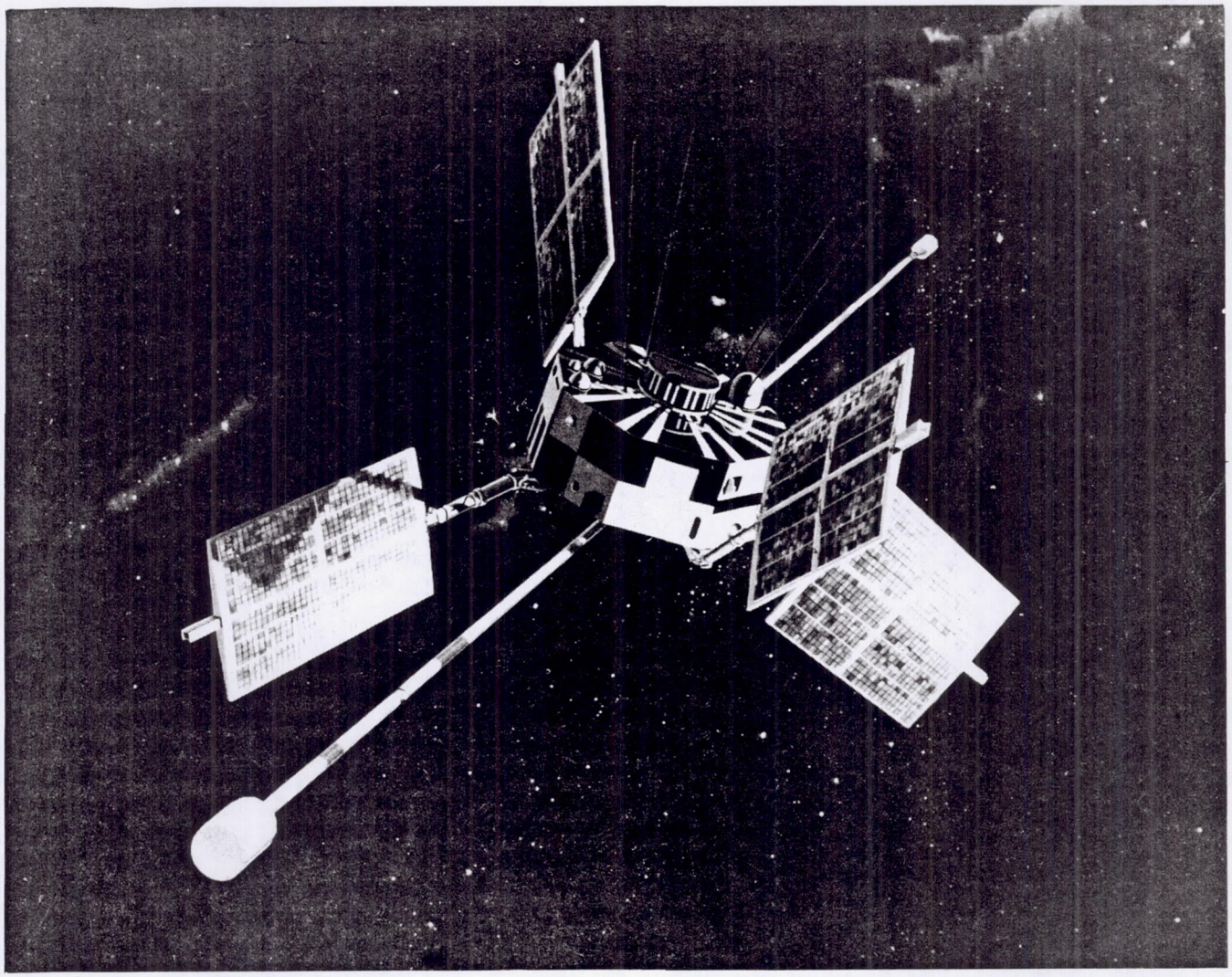
Spacecraft Payload – Experiment instrumentation totaled 51 pounds, included three-axis fluxgate magnetometer, low energy telescope, low energy protons and electron differential energy analyzer, range versus energy loss detector, energy versus range loss detector, low energy proton and alpha detector, ion chamber, solar proton monitoring device, cosmic ray anisotrophy detector/counter, spherical electrostatic analyzer and plasma experiment. Spacecraft systems featured spin stabilization, PFM telemetry with 7-watt transmitter and digital data processor and power supply of 70 watts provided by 6144 n/p solar cells and silver-cadmium batteries.

Project Results – Explorer XXXIV was launched May 24, 1967 from Vandenberg AFB, the first IMP to be launched from the Western Test Range. Elliptical orbit of 154 to 131,187 miles at 67° inclination successfully achieved. All experiments were returning useful data.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, spacecraft prime contractor, experimenter; Electro-Mechanical Research, spacecraft integration; Bell Telephone Laboratories, Southwest Center for Advanced Studies, TRW and Univs. of California, Chicago and Maryland, experimenters; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	P. Butler	NASA-GSFC
PS	F. B. McDonald	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Low Energy Telescope	PI	W. L. Brown	Bell Telephone Laboratories
	CO	L. J. Lanzerotti	Bell Telephone Laboratories
	OI	G. L. Miller	Bell Telephone Laboratories
	OI	C. S. Roberts	Bell Telephone Laboratories
Ion Chamber	PI	K. A. Anderson	University of California, Berkeley
	OI	G. H. Pitt	University of California, Berkeley
C. R. Proton (R vs DE/DX)	PI	J. A. Simpson	University of Chicago
	CO	G. Lentz	University of Chicago
Lepeda, Low Energy Particles	PI	J. A. Van Allen	University of Iowa
	OI	I. A. Frank	University of Iowa
Cosmic Ray Anisotropy	PI	K. G. McCracken	CSIRO
	OI	U. R. Rao	ISRO Satellite Center
	OI	W. C. Bartley	National Academy of Sciences
Electrostatic Analyzer	PI	F. B. Harrison	Unknown
Solar Proton Monitor	PI	C. O. Bostrom	Applied Physics Laboratories
	OI	D. J. Williams	NOAA-ERL
	OI	D. E. Hagge	Unknown
	OI	F. B. McDonald	NASA-GSFC
Electron Analyzer + Selector	PI	K. W. Ogilvie	NASA-GSFC
	OI	T. D. Wilkerson	University of Maryland
Flow Energy Proton + Alpha Detector	PI	F. E. McDonald	NASA-GSFC
	OI	G. H. Ludwig	NOAA-NESS
Cosmic Rays (E vs DE/DX)	PI	F. B. McDonald	NASA-GSFC
	OI	G. H. Ludwig	NOAA-NESS
Magnetic Field Experiment	PI	N. F. Ness	NASA-GSFC
	OI	D. H. Fairfield	NASA-GSFC



Artist's concept of an Interplanetary Monitoring Platform. Using a Delta launch vehicle, IMP carried eleven experiments which studied solar terrestrial relationships by monitoring radiation in interplanetary space, solar wind, and magnetic conditions.

ESRO IIA

Launch Vehicle – Scout.

Spacecraft Description – Polygon with 12 sides, 30 inches across and 33.5 inches high. Solar cells covered sides except for narrow experiment band at midsection. Four telemetry antennas extended from bottom. Weight, 163 pounds.

Project Objectives – ESRO IIA carried seven scientific experiments to study solar and cosmic radiation.

Spacecraft Payload – Experiment instrumentation included energetic particle flux counters, solar and Van Allen belt proton detectors, solar and galactic alpha particle and proton telescope, primary cosmic ray electron counter, hard solar X-ray spectrometer, soft solar X-ray detectors and solar and galactic cosmic ray particle flux and energy spectrum detectors. Spacecraft carried tape recorder for data storage and redundant 2-watt telemetry transmitters. Spin stabilized at 30 to 40 rpm following despin by yo-yo system with spin axis orientation maintained by magnetic coil and spin rate controlled by cold gas system. Ball-in-tube nutation damper used to reduce coning angle. Power supplied by 3456 n/p solar cells and nickel-cadmium batteries. Passive means employed for spacecraft thermal control.

Project Results – ESRO IIA was launched May 29, 1967 from Vandenberg AFB but failed to reach its intended 215 to 680 mile polar orbit due to Scout third stage malfunction.

Major Participants – ESRO European Space Technology Center, spacecraft management; Hawker Siddeley Dynamics, spacecraft prime contractor; Engins Matra, attitude control and power supply systems; TRW, spacecraft general consultant; French Saclay Center for Nuclear Physics and Univs. of Leeds, London (Imperial and University Colleges) and Utrecht, experimenters; NASA Langley Research Center, launch vehicle management; LTV, launch vehicle prime contractor.

MARINER V

Launch Vehicle – Atlas-Agena D, same as ATS 2 mission.

Spacecraft Description – Modified Mariner IV backup spacecraft. Main body a magnesium octagon 50 inches across and 20 inches high. Four solar panels deployed from top, high gain ellipse antenna mounted on superstructure atop body and 88-inch tube on top supported low gain omnidirectional antenna and helium magnetometer. In flight spacecraft 18 feet across solar panels, 9.5 feet high. Weight, 540 pounds.

Project Objectives – Intended to pass within 2000 miles of Venus to provide data on structure of planet's atmosphere and its radiation and magnetic field environment. Mariner V also was designed to return data on interplanetary environment before and after planetary encounter.

Spacecraft Payload – Planetary experiments included S-band occultation based on spacecraft telemetry signals and UV photometry of upper atmosphere atomic hydrogen and oxygen radiation using three photomultiplier tubes. Dual frequency (423.3 and 49.8 mHz) propagation, trapped radiation, magnetic field, solar plasma and celestial mechanics experiments were intended to provide data throughout flight. Data automation system handled data from five experiments. Communication system employed dual transmitter-single receiver, telemetry and command subsystems, tape recorder and high and low gain antennas. 6.5-watt cavity amplifier and 33-1/3 bit per second rate employed early in mission, 10.5-watt TWT and 8-1/3 bit rate later on. Monopropellant (anhydrous hydrazine) engine with 50.7-pound-thrust carried for one or two midcourse corrections. Attitude control provided by redundant six nitrogen gas jet system with input from three gyros, Canopus star tracker, two primary sun sensors, secondary sun sensors, earth sensor, planet sensor and Venus terminator sensor. 17,640 n/p solar cells and silver-zinc batteries supplied 370 watts near earth to 555 watts at Venus. Spacecraft systems programmed by central computer and sequencer. Temperature control maintained by combination of thermal louvers, deployable sunshade, insulation, paint pattern, polished metal surfaces and reference units mounted on three solar panels.

Project Results – Mariner V was launched June 14, 1967 from Cape Kennedy, placed in parking orbit and then injected into interplanetary trajectory. Sun and Canopus acquisition accomplished without incident. Midcourse maneuver carried out with 17.66-second burn June 19, reducing Venus miss distance to approximately 2500 miles. Telemetry bit rate was lowered July 24 to 8-1/3 bits per second. Mariner V was expected to reach Venus on October

19, after 217 million miles of travel. At that time planet was 49.5 million miles from earth. Mariner V was to pass Venus ahead of its orbit around sun, with total occultation time of about 26 minutes. Transmission of science data recorded during flyby was scheduled 14 hours after encounter. Mariner V's post-encounter orbit was to bring it closer to sun than any previous probe.

Major Participants – Jet Propulsion Laboratory, project management, spacecraft prime contractor, Deep Space Network, experimenter; Hughes and Motorola, communication system components; Litton, data automation system; Texas Instruments, spacecraft electronics; TRW, central computer and sequencer, thermal louvers; Cal Tech, Johns Hopkins Univ., Kit Peak Observatory, MIT, NASA Goddard Space Flight Center, Packard Bell, Stanford Univ. and Univs. of California (Los Angeles), Colorado and Iowa, experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics, first stage prime contractor; Lockheed, second stage prime contractor.

Key Spacecraft Personnel		Affiliation
PM	D. Schneiderman	NASA-JPL
PM	T. Parks	NASA-JPL
PS	C. W. Snyder	NASA-JPL
CO	D. Allison	NASA Headquarters
CO	G. A. Reiff	NASA Headquarters
CO	C. Wilson	NASA-JPL

Experiment	Experiment Personnel		Affiliation
Occultation S-Band	PI	A. J. Kliore	NASA-JPL
Two Frequency	PI	V. R. Eshleman	Stanford University
Beacon	OI	T. A. Croft	SRI International
Faraday Cup	PI	H. S. Bridge	Massachusetts Institute of Technology
Trapped Radiation Detector	PI	J. A. Van Allen	University of Iowa
Helium Magnetometer	PI	E. J. Smith	NASA-JPL
UV Photometer	PI	C. A. Barth	University of Colorado
Celestial Mechanics	PI	J. D. Anderson	NASA-JPL

SURVEYOR IV

Launch Vehicle – Atlas-Centaur: 388,000-pound-thrust Atlas first stage with two 670-pound-thrust vernier engines for roll directional control; 30,000-pound-thrust Centaur second stage. First stage radio guided, second stage inertially guided. Height: 113 feet.

Spacecraft Descriptions – Surveyor spaceframe was a triangular aluminum structure which provides mounting surfaces and attachments for landing gear, main retrorocket engine, vernier engines, and associated tanks, thermal compartments, and other assemblies. Planar high-gain antenna and solar panel, supported by a positioner movable along four axes, mounted on mast which extends from top. A crushable aluminum footpad was attached to the end of each leg of the tripod landing gear, hinged to each of the three lower corners of the frame and folded into nose shroud during launch. Two omnidirectional, conical antennas were mounted on the ends of folding booms hinged to the spaceframe. The spacecraft was about 10 feet high and, with landing gear extended, placed within a 14-foot circle. Weight at launch: 2290 pounds; landing weight: about 625 pounds.

Project Objective – The Surveyor program, a series of seven unmanned lunar softlanding lights which began in May of 1966, yielded a wealth of photos and engineering and scientific data in support of selection of Apollo landing sites. Of the six launches, four have been successful, providing sufficient information to complete planned site survey. Surveyor IV soft-landed in Sinus Medii at almost dead center of front face of moon – 1°20′W longitude and 0°25′N latitude – a site considerably rougher than those of the two previous Surveyor landings but one required to provide a variety of Apollo landing site options. Flight regime of Surveyor IV required lunar approach at 36° from vertical – a greater angle than those of its predecessors. Like Surveyor III, Surveyor IV was to dig into lunar soil under the eye of its television camera and return pictures of lunar landscape, as well as data on strength, texture, and cohesiveness of lunar soil. In addition, Surveyor IV was to determine presence of magnetic particles in lunar soil.

Spacecraft Payload – Television camera, surface scoop sampler, and magnet. Survey television camera, capable of providing 200- or 600-line pictures, mounted vertically on crossbar near top of spaceframe and pointed at mirror which can swivel 360° and tilt up to reflect horizon or down to reflect leg of spaceframe. Camera iris setting adjustable automatically or by earth command. Field of view adjustable from 6.4 x 6.4 feet to 25.4 x 25.4 feet. Two flat beryllium mirrors mounted on spaceframe to provide additional coverage of area under spacecraft. Adjustable filter wheel provides clear, colored, or

polarizing filters. Surface sampler experiment similar to that on Surveyor III: scoop about 5 inches long and 2 inches wide attached to an arm extendable up to 5 feet. Arm was hinged horizontally and vertically to spaceframe, capable of digging and scooping to 18-inch depth within 24-square-foot area, performing penetration tests by dropping from various heights, and performing bearing strength tests by pressing down on lunar surface. Two small bars, each 2 inches x 1/2 inch x 1/8 inch, one magnetic and one non-magnetic, mounted on footpad #2 in view of camera to enable determination, by visual comparison, of presence of particles in lunar soil. Spacecraft velocity and attitude control provided by sun acquisition sensor, sun and Canopus sensors, inertial reference unit, altitude marking radar, inertial burnout switch, radar altimeter and doppler velocity sensor, flight control electronics, and six nitrogen gas jets. Propulsion system utilized three variable-thrust (30 to 104 pounds) engines and solid propellant retrorocket with 8000 to 10,000 pounds of thrust. Communication system employed two low-gain antennas for 200-line photos, high-gain antenna for 600-line photos, and redundant 10-watt transmitters. Power supplied by 3960 n/p solar cells and silver-zinc batteries. Active thermal control provided by thermal compartments; otherwise, passive techniques were employed – e.g., paint patterns, polished surface, insulation.

Project Results – Surveyor IV was launched on July 14, 1967 from Cape Kennedy into a direct lunar ascent trajectory similar to that employed with Surveyors I and II. A midcourse maneuver brought the anticipated touchdown to within 2.4 miles southwest of the target bullseye. All systems indicated normal performance until two seconds before retrorocket burnout (2½ minutes before touchdown), when signal was abruptly lost. Efforts to reestablish contact with Surveyor IV, which theoretically could have landed in completely automatic mode, were abandoned on July 18, 1967.

Major Participants – JPL, spacecraft management, tracking; Hughes, spacecraft prime contractor; Ryan, radar altimeter and doppler velocity sensor; Thiokol, retro and vernier propulsion; Cal Tech and U.S. Geological Survey, experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics, launch vehicle prime contractor.

Experiment	Experiment Personnel	Affiliation
Television Camera	PI E. M. Shoemaker	California Institute of Technology
	OI R. A. Altenhofen	U.S. Geological Survey
	OI G. P. Kuiper	University of Arizona
	OI E. C. Morris	U.S. Geological Survey
	OI J. J. Rennilson	California Institute of Technology
	OI E. A. Whitaker	University of Arizona
Surface Mechanics	PI R. F. Scott	California Institute of Technology
	OI R. M. Haythornwaite	Pennsylvania State University
	OI R. A. Liston	U.S. Army

EXPLORER XXXV (IMP E)

Launch Vehicle – Thrust Augmented Delta (TAD): Thor first stage with three strap-on solid-propellant motors and total thrust of 333,500 pounds, 7900-pound-thrust second stage, and 6200-pound-thrust FW-4D solid-propellant third stage. First and second stages radio guided, third stage spin stabilized. Height: 92 feet.

Spacecraft Description – Same as Explorer XXXIII; similar to Explorers XVIII, XXI, and XXVIII, except that retrorocket was mounted atop spacecraft in place of usual magnetometer boom. Main body an octagon 28 inches across and 8 inches high. Four whip antennas projected from top; two 6-foot magnetometer booms and four solar panels extended from main body. Weight: 230 pounds including 80-pound retro motor.

Project Objectives – Study solar wind and interplanetary fields at lunar distances, either by attaining earth orbit apogee of at least 250,000 miles or by attaining lunar orbit. If lunar orbit was attained, additional objectives were to include investigation of lunar radiation environment, dust distribution around the moon, lunar gravitational field, and the weak lunar ionosphere.

Spacecraft Payload – Included in the 10 experiments on board were two flux-gate magnetometers, three radiation sensors, a plasma probe, and a micrometeoroid flux detector; two passive experiments employing telemetry transmissions and tracking beacons; and one engineering experiment concerning solar cell damage. Spacecraft communication system included PFM-PM telemetry, 7-watt transmitter, and digital data processor. Average power of 43 watts supplied by n/p solar cells and silver-cadmium batteries. Solid-propellant retro motor intended to provide 916-pound-thrust for 20 seconds. Spin stabilized at 28 rpm.

Project Results – Explorer XXXV was launched on July 19, 1967 from Cape Kennedy. Attitude control gas jets were fired during a 3-hour period beginning about 38 hours after liftoff to adjust spacecraft's point direction in preparation for retro engine firing. Retro firing occurred approximately 19 hours later, placing spacecraft into lunar orbit of 500/4600 miles at 147°. Two hours after retro firing, empty motor case was jettisoned as planned. Significant preliminary experimental results indicated that no supersonic shock front precedes moon to impede flow of solar wind toward lunar surface, moon has practically no magnetic field (hence it has no complex magnetosphere envelope such as that formed around earth), and – because of lack of magnetic field – moon has no radiation belts or evidence of existence of lunar ionosphere. Also discovered was a sizeable empty cavity or solar wind void behind moon and away from sun. This "wake" region, estimated at more than 100,000 miles in length, tends to distort weak interplanetary magnetic field which flows from sun along with solar wind. Data indicate moon's average electrical conductivity is low; internal temperatures estimated at below 1800°F. All experiments continued to return useful data. Design lifetime: 1 year.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, spacecraft prime contractor, experimenters; Westinghouse, spacecraft integration; Thiokol, retromotor; NASA Ames Research Center, MIT, Univs. of Iowa and California, UCLA, experimenters; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	P. G. Marcotte	NASA-GSFC
PS	N. F. Ness	NASA-GSFC
CO	A. W. Schardt	NASA Headquarters
CO	F. W. Gaetano	NASA Headquarters
CO	J. J. Brahm	NASA-GSFC
CO	P. L. Heffner	NASA-GSFC
CO	J. Barsky	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Geiger Mueller Counter + Solid State Detector	PI	J. A. Van Allen	University of Iowa
	CO	R. Brechwald	University of Iowa
Energetic Particle Flux	PI	K. A. Anderson	University of California, Berkeley
	OI	G. H. Pitt	University of California, Berkeley
3 Axis Fluxgate Magnetometer	PI	C. P. Sonett	University of Arizona
	OI	J. H. Wolfe	NASA-ARC
	OI	R. W. Silva	TRW Systems Group
	OI	J. W. Kerwin	NASA-ARC
	CO	D. S. Colburn	NASA-ARC
Magnetometer	PI	N. F. Ness	NASA-GSFC
	OI	K. W. Behannon	NASA-GSFC
Micrometeorites	PI	W. M. Alexander	Baylor University
	OI	J. L. Bohn	Temple University
Faraday Cup	PI	H. S. Bridge	Massachusetts Institute of Technology
Retard Potential Analyzer E + P	PI	G. P. Serbu	NASA-GSFC
	OI	E. J. Maier	NASA-GSFC
Cislunar RF Beacon	PI	A. M. Peterson	Stanford University
	OI	G. L. Tyler	Stanford University
Selenodetic Studies	PI	W. M. Kaula	University of California, Los Angeles
Solar Cell Damage	PI	L. W. Slifer, Jr.	NASA-GSFC

OGO IV

Launch Vehicle – TAT-Agena D: 170,000-pound-thrust Thor first stage augmented by three strap-on solid motors at 54,000 pounds thrust each. Agena D second stage, 16,000 pounds thrust. First stage radio and inertially guided, second stage inertially guided. Height: 97 feet.

Spacecraft Description – Rectangular main body 6 feet long, 3 feet wide, 3 feet deep. Appendages include two 22-foot booms, one extending from each end, as well as four 4-foot booms, two solar panels 7½ feet long and 6 feet wide, and two orbital plane experiment packages 18 inches long, 10 inches wide, and 10 inches deep. Weight: 1216 pounds.

Project Objectives – Study the relationship between the sun and earth's environment during a period of increased solar activity.

Spacecraft Payload – Twenty experiments: particular emphasis was placed upon particle activity, aurora and airglow, the geomagnetic field, the neutral and ionized composition of the atmosphere, and the electromagnetic energy sources contributing to ionization and atmospheric heating. Two solar arrays, containing 33,000 solar cells, provide about 560 watts of electric power, stored in two 12-ampere-hour nickel-cadmium batteries. The attitude control system provided three-axis stabilization, consisting of horizon scanner, sun sensors, gas jets, electrically-driven flywheels (utilized to store and dump momentum), and associated electronics. Combined active and passive thermal control system utilized heaters, radiating panels, and aluminum louvers. The communications and data handling system included two redundant data handling units that transmit in real time or store up to 6 hours of data.

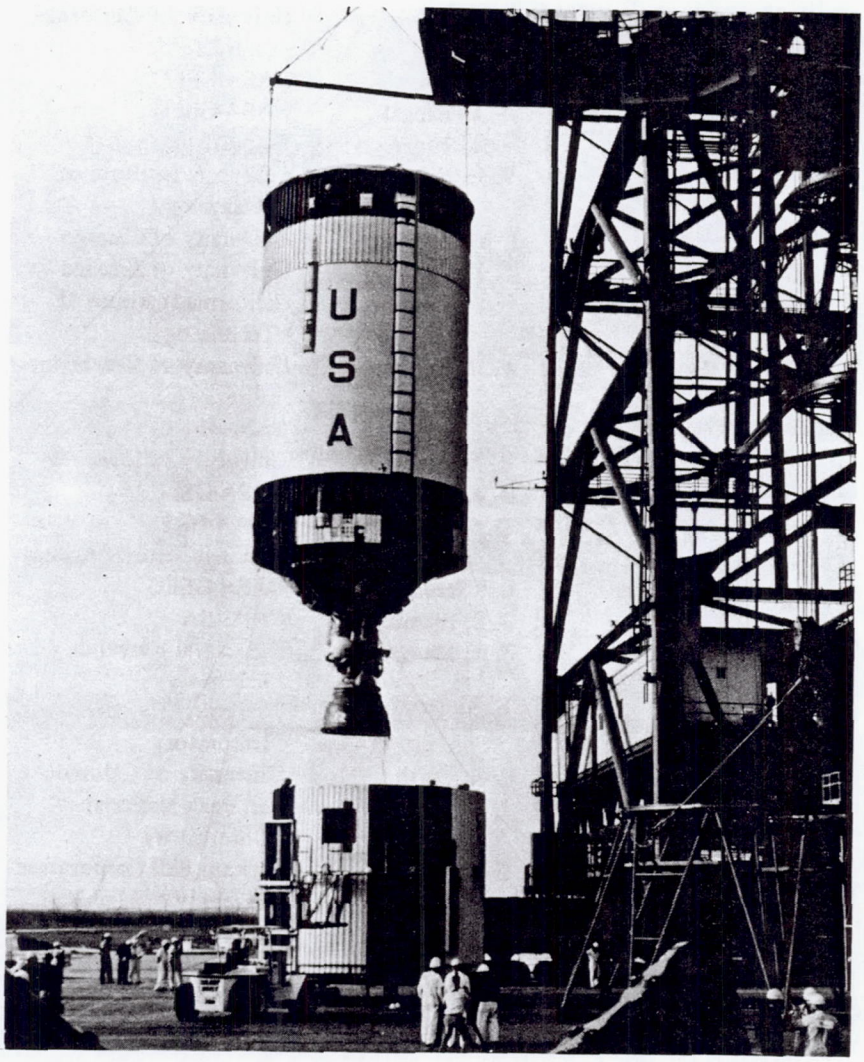
Project Results – OGO IV was launched on July 28, 1967 into a near-polar orbit of 256/564 miles, has completed its primary objective of collecting data while remaining stable in all three axes for more than 50 days. About a week after launch unexpected oscillation occurred in 60-foot experimenter's antenna, threatening to deplete the supply of control gas. Problem was corrected by commanding the gas system off, and by activating it only to dump stored momentum from the reaction wheels. OGO IV continued to operate stabilized in all three axes, primarily on reaction wheel control, with 18 of 20 experiments providing useful data.

Major Participants — NASA Goddard Space Flight Center, spacecraft management, experimenter; Lewis Research Center, launch vehicle management; TRW, spacecraft prime contractor; AFCRL, Cal Tech, Darthmouth College, JPL, Kitt Peak National Observatory, Rice Univ., Smithsonian Astrophysical Observatory, Stanford Univ., UCLA, U.S. Naval Research Laboratory, and Univs. of Chicago, Colorado, Iowa, Michigan, Minnesota and Paris, experimenters; McDonnell Douglas, first stage prime contractor; Lockheed, second stage prime contractor.

Key Spacecraft Personnel		Affiliation
PM	W. E. Scull	NASA-GSFC
PS	N. W. Spencer	NASA-GSFC
MG	C. D. Ashworth	NASA Headquarters
SC	R. F. Fellows	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Radio Astronomy, 2, 5, 2. OMHz	PI	F. T. Haddock	University of Michigan
	OI	W. Potter	University of Michigan
VLF Receiver	PI	R. A. Helliwell	Stanford University
	OI	L. H. Rorden	Devlco Incorporated
VLF Receiver	PI	M. G. Morgan	Dartmouth College
Low Frequency Magnetic Fluctuations	PI	E. J. Smith	NASA-JPL
	OI	R. E. Holzer	University of California, La Jolla
Magnetic Field Survey	PI	J. C. Cain	NASA-GSFC
	OI	R. A. Langel	NASA-GSFC
Cosmic Ray + Polar Region Ion	PI	H. R. Anderson	Rice University
	OI	V. H. Neher	California Institute of Technology
Energetic Particles Survey	PI	J. A. Simpson	University of Chicago
	OI	C. Y. Fan	University of Arizona
	OI	E. C. Stone	California Institute of Technology
Galactic + Solar Cosmic Rays	PI	W. R. Webber	University of New Hampshire
Trap. and Precipitation Particles	PI	J. A. Van Allen	University of Iowa
	OI	L. A. Frank	University of Iowa
Low Energy Auroral Particles	PI	R. A. Hoffman	NASA-GSFC
	OI	D. S. Evans	NOAA-ERL
	CO	F. W. Berko	National Security Agency
Airglow Photometer	PI	E. I. Reed	NASA-GSFC
	OI	J. E. Blamont	CNRS-SA
Geophysical Lyman Alpha + UV Airglow	PI	P. W. Mange	U.S. Naval Research Laboratory
	OI	R. R. Meier	U.S. Naval Research Laboratory
UV Airglow Spectrometer	PI	C. A. Barth	University of Colorado
	OI	L. J. Wallace	Kitt Peak National Observatory
	OI	E. F. Mackey	Packard-Bell Corporation
Neutral Particle Ion	PI	L. M. Jones	University of Michigan
	OI	R. J. Leite	University of Michigan
Ion Composition	PI	H. A. Taylor, Jr.	NASA-GSFC
	OI	N. W. Spencer	NASA-GSFC
Neutral Particle Detector	PI	G. P. Newton	NASA-GSFC

Experiment	Experiment Personnel	Affiliation
Micrometeorite Detector	PI C. S. Nilsson	Flinders University of Southern Australia
Positive Ion Study	PI S. S. Chandra	NASA-GSFC
	OI J. J. Donley	NASA-GSFC
	OI R. E. Bourdeau	NASA-GSFC
Solar UV Spectrometer	PI H. E. Hinteregger	USAF Geophysical Laboratory
	OI D. E. Bedo	USAF Geophysical Laboratory
Solar X-Ray	PI R. W. Kreplin	U.S. Naval Research Laboratory
	OI T. A. Chubb	U.S. Naval Research Laboratory
	OI H. D. Friedman	U.S. Naval Research Laboratory



Second stage of uprated Saturn I launch vehicle is being placed onto adapter ring for mating to launch vehicle, in preparation for Apollo/Saturn-206 mission at Complex 37, Cape Kennedy, Fla. The engine was capable of producing 200,000 pounds of thrust.

LUNAR ORBITER V

Launch Vehicle – Atlas-Agena D: 391,000-pound-thrust Atlas SLV-3 first stage, 16,000-pound-thrust Agena D second stage. First stage radio guided, second stage inertially guided. Height: 105 feet.

Spacecraft Description – Identical to earlier Lunar Orbiters: truncated cone structure from whose base extends a low-gain antenna and a parabolic high-gain antenna at 180° from each other and four solar panels at 90° intervals. Main body covered by aluminized mylar reflective thermal blanket. Velocity control engine nozzle extends through heatshield at top of cone structure. Folded for launch, entire structure measures 5 feet in diameter by 5½ feet in height. With solar panels and antennas deployed, maximum span is 18½ feet across antenna booms and 12 feet 2 inches across solar panels. Weight: 860 pounds.

Project Objectives – Revisit and photograph five potential Apollo landing sites previously viewed by Lunar Orbiters I, II, and III; photograph several locations being considered for future Surveyor landings. Take low-altitude telephoto pictures of 36 sites of scientific interest to permit more detailed observation of lunar surface than previously possible. Additional photography to raise coverage of hidden lunar surface to more than 95%. Secondary mission: monitor proton radiation and meteoroids in vicinity of moon.

Spacecraft Payload – Photographic laboratory contained within egg-shaped pressure shell, all parts weighing under 150 pounds. Included two cameras, one for wide angle and the other for telephoto coverage, which viewed moon through a protective window of quartz. Quartz window in turn protected by mechanical flap in thermal blanket. Film supply spool carried 260 feet of 70-mm SO-243 unperforated film, sufficient for at least 212 dual exposure frames. In addition to cameras, photo laboratory included film processing and photo readout (scanning) systems. Other subsystems were conventional solar panel-storage battery power system; attitude control system featuring both celestial and inertial reference units, programmer, and reaction control thrusters; 100-pound-thrust hypergolic-fueled velocity control system; S-band communication system; and passive temperature control system.

Project Results – Fifth and final Lunar Orbiter was launched from Cape Kennedy on August 1, 1967. First Agena burn injected spacecraft into parking orbit, second into 89-hour translunar orbit. Following injection into lunar orbit, spacecraft returned 213 frames, increasing lunar photographic coverage to better than 99%. As long as sufficient attitude control gas remained to power a controlled crash, Lunar Orbiter V was allowed to remain in orbit for use as tracking target by NASA's Manned Space Flight Network.

Major Participants – NASA Langley Research Center, spacecraft management, experimenter; Boeing, spacecraft prime contractor; Eastman Kodak,

camera system; RCA, communication and power systems; Marquardt, mid-course engine; JPL, Deep Space Network management, experimenter; NASA Lewis Research Center, launch vehicle management; General Dynamics, first stage prime contractor; Lockheed, second stage prime contractor.

Experiment	Experiment Personnel	Affiliation
Lunar Photography	PI L. J. Kosofsky	NASA Headquarters
	OI I. G. Recant	NASA-LARC
Selenodesy	PI W. H. Michael, Jr.	NASA-LARC
Meteoroid Detectors	PI C. A. Gurtler	NASA-LARC
Radiation Measurements	PI T. Foelsche	NASA-LARC

BIOSATELLITE II

Launch Vehicle – First two stages of Thrust Augmented Delta (TAD): Thor first stage with three strap-on solid motors and thrust of 328,000 pounds; 7800-pound-thrust second stage. Both stages radio guided. Height: 92 feet.

Spacecraft Description – Similar to Biosatellite I: cylinder-cone connected to blunt cone end. Overall length: 6 feet, 9 inches. Consisted of three major segments: adapter, re-entry vehicle, and recovery capsule. Adapter was a 57-inch-diameter cylinder whose forward end tapered to a 40-inch-diameter opening, which in turn connected to the re-entry vehicle. Re-entry vehicle consisted of a bowl-shaped heat shield 40 inches in maximum diameter and 33 inches deep with ablative surface material of phenolic nylon, an aft thermal cover, and the thrust cone with retro-rocket and cold gas spin and de-spin jets. Thrust cone assembly fastened to aft end of heat shield to form aft end of re-entry vehicle. Recovery capsule, a covered aluminum bowl 31 inches in diameter with 6 cubic feet of payload space, mounted inside heat shield and contained experimental payload together with associated support equipment. Weight: 940 pounds.

Project Objectives – Conduct biological experiments during 3 days in low earth orbit. Chief experimental objectives: determine whether changes produced in organisms by radiation are slowed or hastened by weightless environment. Re-entry atmosphere over Pacific Ocean; to be recovered either during parachute descent or from the ocean.

Spacecraft Payload – Total of 13 experiments included seven radiation experiments, isolated in a tungsten-nickel-copper sphere and placed concentrically around a Strontium 85 radiation source so as to receive one of nine radiation doses – from 200 to 500 roentgens. Radiation experiments, contained in forward end of capsule, were walled off from rest of capsule by a laminated aluminum-tungsten-aluminum backscatter shield. Aft end of capsule carried general biology experiments and control version of radiation experiments. General biology experiments were concerned with cell division, alteration in division and growth in cells of a developing embryo, effects on basic structure of protoplasm, effects on enzymes (those concerned with cell division and those governing energy conversion), orientation to gravity of leaves, roots, and shoots of various plants. Life support system consisted of high-pressure sphere containing air, a circulating fan, and metering and pressure regulating systems, as well as silica gel absorbers to maintain 40-70% relative humidity. Attitude control system, which maintained spacecraft rotation to about once every 20 minutes, consisted of stored high-pressure nitrogen, six cold gas thruster jets, three motion-sensing gyros, a magnetometer, and two infrared scanners. Two telemetry systems with 2-watt transmitters, one located in adapter section for housekeeping data during mission, the other in experiment capsule to return similar data after separation. Additional information stored by tape recorder in experiment capsule. Silver-zinc batteries provided power during flight, with smaller batteries used for retrofire and recovery. Ground commands and five on-board programmers employed to initiate spacecraft operations and re-entry events. Infrared horizon scanners and magnetometer provided data for spacecraft alignment prior to re-entry. After separation, two cold gas

jets used to spin up spacecraft to 57 rpm, solid-propellant 10,200-pound-thrust retrorocket to ignite, and vehicle to be despun to 12 rpm maximum by second pair of gas jets. Ablative heat shield designed to dissipate entry heating. Drogue parachute to deploy at 80,000 feet, main parachute at 10,000 feet. Recovery system also included radio transmitters and dye markers in case air recovery failed.

Project Results – Biosatellite II was launched on 7 September 1967 from Cape Kennedy into a 188/203-mile orbit at 33.5° inclination. Spacecraft re-entry was initiated after 45 hours in orbit – 17 orbits earlier than planned – because of communications difficulties and approaching tropical storm in recovery area. Air recovery by USAF was successful, and the recovery capsule was flown to Hickam AFB in Honolulu. Despite premature recovery, over 71% of information sought was acquired. Among the early findings: the 75 wheat seedlings grew as much in two days of weightlessness as the same plants would have grown in three days on earth. Later analysis determined that greatest effects of weightlessness were seen in young and actively-growing cells and tissues; rapidly-dividing cells with high metabolic activity showed more effects than mature cells which divide more slowly. Generally, plants had trouble maintaining proper orientation in weightlessness; some plant structures, mechanisms, and biochemical activity seemed to be affected. Animal cells seemed least affected by weightlessness. When plant and animal structures undergo radiation in zero gravity, both seem to suffer greater damage than the same organisms on earth; damage seemed to occur principally in young, rapidly-dividing cells or in active reproductive cells, not in mature structural cells. Some experiments indicated that growth and metabolism of rapidly-dividing cells are slowed by absence of gravity, giving time for repair of cells damaged by radiation in weightless state.

Major Participants – NASA Ames Research Center, spacecraft management; GE, spacecraft prime contractor, experimenter; Thiokol, retrorocket; Colorado State Univ., NASA, Dartmouth College, Emory Univ., Resources Planning and Control Corp., North American Rockwell, Univ. of Wisconsin, Brookhaven National Laboratory, Oak Ridge National Laboratory, State Univ. of North Carolina, Southwestern Univ. at Memphis, Univ. of California, Rice Univ., Bowling Green State Univ., NUS Corp, experimenters; NASA Goddard Space Flight Center; launch vehicle management; McDonnell Douglas, launch vehicle prime contractor.

Experiment	Experiment Personnel	Affiliation
Weightlessness on Wheat Seedling	PI S. W. Gray	Emory University
	OI B. F. Edwards	Emory University
Growth Physiology of Wheat Seedling	PI C. J. Lyon	Dartmouth College
Biochemistry in Wheat Seedling	PI H. M. Conrad	Rocket Propulsion Corporation
	OI S. P. Johnson	North American Aviation

Experiment	Experiment Personnel		Affiliation
Effects on Egg of Rana Pipiens	PI	R. S. Young	NASA Headquarters
	OI	J. W. Tremor	NASA-ARC
Mutation Respons. Habrobracon	PI	R. C. Von Borstel	Oak Ridge National Laboratories
	OI	R. L. Amy	Southwestern University
	OI	D. S. Grosh	North Carolina State University
	OI	R. H. Smith	Oak Ridge National Laboratories
	OI	A. R. Whiting	Oak Ridge National Laboratories
Liminal Ang. of Plagiogeot.	PI	S. P. Johnson	North American Aviation
	OI	T. Tibbitts	University of Wisconsin
Effects on Tribolium Pupae	PI	J. V. Slater	University of California, Berkeley
	OI	B. Buckhald	University of California, Berkeley
Effects on Drosophila Larvae	PI	I. I. Oster	Bowling Green State University
Damage to Reproductive Cycle	PI	L. Browning	Rice University
Genetic + Cytologic Studies	PI	A. H. Sparrow	Brookhaven National Laboratories
	OI	L. A. Schairer	Brookhaven National Laboratories
Comb. Effects on Neurospora	PI	F. J. Deserres	Oak Ridge National Laboratories
	OI	B. B. Webber	Oak Ridge National Laboratories
Spc. + Rad. Eff. on Lysogentic B.	PI	R. H. T. Mattoni	NUS Corporation
	OI	W. T. Ebersold	University of California, La Jolla
	OI	F. Eiserling	University of California, La Jolla
	OI	E. C. Keller, Jr.	NASA Headquarters
	OI	W. Romig	University of California, La Jolla
E. Weightlessness on Amoeba	PI	R. W. Price	Colorado State University
	OI	D. R. Eckberg	General Electric Corporation
	OI	J. W. Abel, Jr.	Colorado State University

SURVEYOR V

Launch Vehicle – Atlas-Centaur: 395,340-pound-thrust Atlas SLV-3C first stage, 30,000-pound-thrust Centaur second stage. First stage radio guided, second stage inertially guided. Height: 117 feet.

Spacecraft Description – Basically identical to Surveyor IV except for substitution of alpha scattering experiment in place of surface sampling experiment.

Project Objectives – Further development of lunar soft-landing technology and provision of data in support of Apollo. Primary objectives of this mission: soft-land 24°E longitude and 1°N latitude, in the southern part of Mare Tranquillitatis; return television photos of lunar surface, data on chemical characteristics of lunar soil.

Spacecraft Payload – Camera system identical to that on Surveyor IV except for substitution of curved for flat beryllium mirrors mounted on spaceframe to extend area of camera coverage underneath spacecraft. Magnet experiment carried on Surveyor IV also carried on Surveyor V. Chief difference from earlier Surveyors was addition of alpha scattering experiment to determine chemical composition of lunar soil. On-board units comprising the experiment: alpha scattering sensor head, instrument electronics and electronics auxiliary, deployment mechanism, thermal compartment, thermal control and heater assembly, and wiring harnesses and attachment hardware. Sensor unit, containing curium 252, was to be lowered by deployment mechanism, then to bombard section of lunar surface and detect presence of backscattered alpha particles and protons. Electronics unit contained logic circuitry to measure pulse width and put the data into binary words; binary words (both alpha and proton events) then applied to subcarrier oscillators contained in electronics auxiliary. Subcarrier oscillator outputs then routed to central signal processor for final summing prior to transmission. Auxiliary, which contained decoder and swiching circuits, provided control interface between experiment operations and central command decoding and power subsystems.

Project Results – Surveyor V was launched on September 8, 1967 from Cape Kennedy and, following first stage separation, was injected into a parking orbit by the first burn of the Centaur second stage. After a brief coasting period in orbit, Centaur's second burn injected spacecraft into lunar transfer trajectory. A depleted helium supply, due to failure of helium pressure valve during midcourse correction maneuver, necessitated emergency development of a new descent profile, and Surveyor V successfully soft landed on

September 10, 1967 at 1.45°N and 22.25°E – within 18 miles of intended target – and all experiments were performed successfully. Lunar soil found to resemble earth's basaltic rock. Photos of magnetic bars indicated presence of small amounts of ferrous material in lunar soil. Alpha scattering experiment indicated soil composition as 53 to 63% oxygen; 15.5 to 21.5% silicon; 10 to 16% sulphur, iron, cobalt, and nickel; 4.5 to 8.5% aluminum; and small quantities of magnesium, carbon, and sodium. Presence of hydrogen was not determined. Camera system returned over 18,000 photos, quality of which exceeded that of previous Surveyor photos. Vernier engines were re-started, burned for 0.2 second; subsequent photos indicated no appreciable dust cloud was created or craters formed by exhaust. Following shutdown period during two week lunar night, communications were resumed in an attempt to perform lunar wobble study (i.e., how much moon wobbles in its orbit) in conjunction with Surveyor VI, but signals from both spacecraft weakened and eventually failed.

Major Participants – University of Chicago and U.S. Geological Survey, experimenters. Otherwise, same as Surveyor VI.

Key Spacecraft Personnel		Affiliation
PS	L. D. Jaffe	NASA-JPL

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	F. M. Shoemaker	California Institute of Technology
	OI	R. M. Batson	U.S. Geological Survey
Alpha Scatter	PI	A. L. Turkevich	University of Chicago
	OI	F. J. Franzgrote	NASA-JPL
Surface Mechanics	PI	R. F. Scott	California Institute of Technology
	OI	R. M. Haythornwaite	Pennsylvania State University
	OP	R. A. Liston	U.S. Army
Hard. of Surface	PI	S. A. Batterson	NASA-LARC
Seismic Studies	PI	G. H. Sutton	University of Hawaii
	OI	W. M. Ewing	Unknown
	OI	F. Press	Massachusetts Institute of Technology
Lunar Experiment	PI	J. I. Rohn	Temple University
	OI	W. M. Alexander	Baylor University

INTELSAT IIF - 4

Launch Vehicle – Thrust Agumented Delta (TAD): Thor first stage with three strap-on solid propellant motors and total thrust of 333,500 pounds, 7900-pound-thrust second stage, and 6200-pound-thrust FW-4D solid-propellant third stage. First and second stages radio guided, third stage spin stabilized. Height: 92 feet.

Spacecraft Description – Similar to Intelsat IIF-2: cylinder 56 inches in diameter and 26.5 inches high, with 18-inch communication antenna mounted on top, apogee motor nozzle and eight telemetry antennas extended from bottom. Aluminum honeycomb sides faced with solar cells, ends covered by thermal shields. Like earlier Intelsats, Intelsat IIF-2 added thermal shield to protect exposed end of apogee motor. Advanced satellite antenna design permitted direct contact with several ground stations simultaneously and provided for greater commercial use without loss of signal power. Weight at launch: 357 pounds; weight in orbit: 192 pounds.

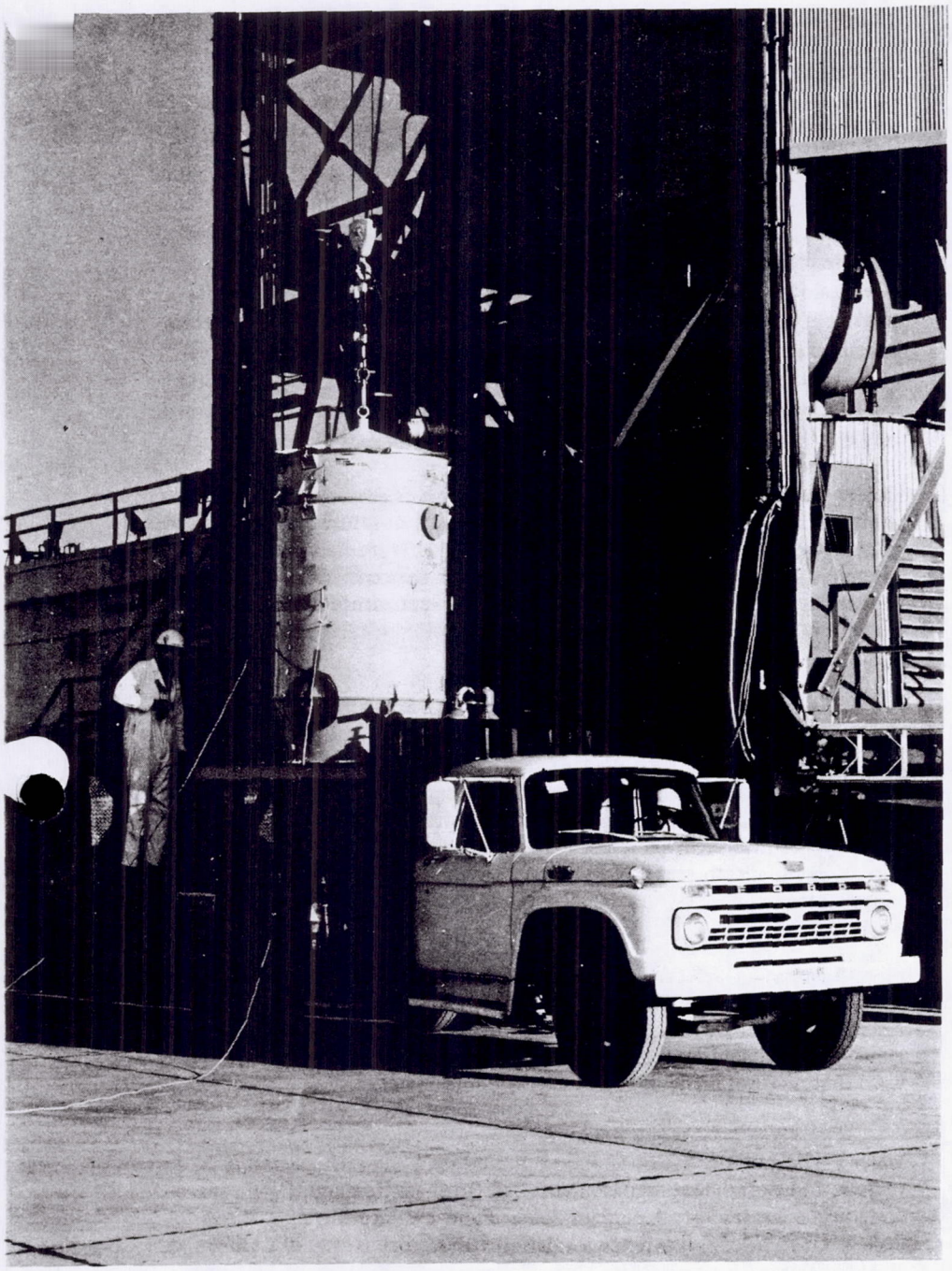
Project Objectives – To provide 24-hour transoceanic commercial communication service among ground stations in Thailand, Australia, Japan, Philippines, Hawaii, and Washington State for all forms of transmission: telephone, teletype, digital data, facsimile, and television.

Spacecraft Payload – Communication system utilized two redundant linear repeaters with 125 mc bandwidth and 6 db, and four 6-watt TWT's – up to three used at one time. Omnidirectional biconical horn with ERP of 18 watts employed as transmitting antenna. Provided 240 two-way voice channels. Subsystems included hydrogen peroxide gas jets for spin stabilization and station-keeping. Power supply of 85 watts furnished by nickel-cadmium batteries and 12,756 n/p solar cells. Solid-propellant apogee motor utilized for injection into synchronous orbit. Passive thermal control employed, plus 3-watt strip heater mounted at base of apogee motor nozzle.

Project Results – Launched on September 28, 1967 from Cape Kennedy into an elliptical transfer orbit. Three days later the apogee motor was fired, placing the spacecraft into a near-synchronous orbit of 22,220/22,245 at 0.9°. Current usage rate was near maximum capacity.

Major Participants – Comsat Corp., spacecraft management; Hughes, spacecraft prime contractor; Aerojet General, apogee motor; NASA Goddard Space Flight Center, launch vehicle management; McDonnell Douglas, launch vehicle prime contractor.

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OSO-IV arrives at launch site.

OSO IV

Launch Vehicle – Delta: Modified Thor first stage with 172,000 pounds of thrust, 7500-pound-thrust second stage, and 6200-pound-thrust third stage. Height: 92 feet.

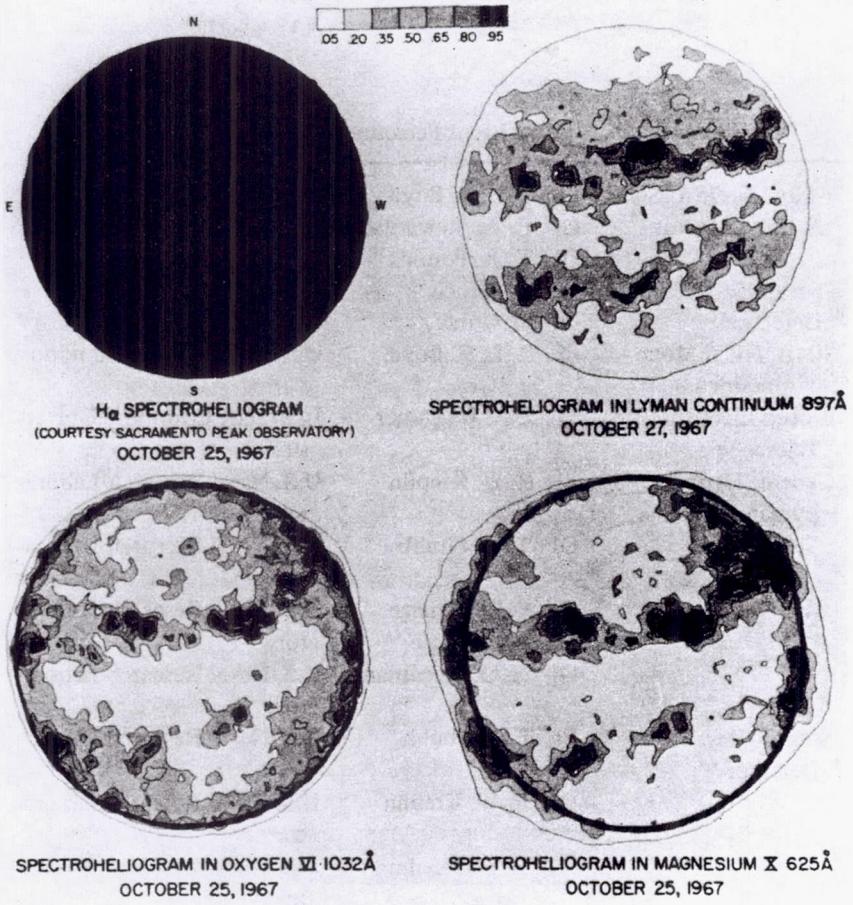
Spacecraft Description – Same basic two-section design as previous OSO's: spinning base, a nine-sided drum 15 inches in height and 44 inches in diameter, revolved at 30 rpm allowing six experiments to scan the sun. Base also held power, command, and communications subsystems. Diameter of 44 inches extended to 101 inches when three boom arms were extended for stabilization. Nitrogen gas in spheres on arms controlled spin rate. Solar panels and pointed instruments, mounted on near-circular 22-inch high sail, face sun during daytime. Magnetic bias coil augmented pitch control systems, reduced pitch gas usage. Pointing accuracy: 0.5 arc minutes. Power supply of 38 watts provided by 2016 n/p solar cells. Maximum load: 26 watts. Weight: 597 pounds. Design lifetime: 6 months.

Project Objectives – Continuation of OSO program begun with first launch in March of 1962: to better understand the sun's structure and determine solar influence upon earth. Six of nine experiments studied the structure, dynamics, and chemical composition of the sun by examining solar X-rays, gamma rays, and ultraviolet radiation. Three experiments studied the celestial sphere. Several experiments were extensions of studies begun on OSO's I and II.

Spacecraft Payload – At 255 pounds, experiments represent 0.427 of total spacecraft weight. Three pointed experiments in sail are ultraviolet spectrometer (spectrophotometer and spectroheliograph), X-ray spectroheliograph, and X-ray spectrometer. Six wheel experiments are celestial X-ray telescope, proton-electron telescope, helium II and hydrogen I monochromator, X-ray spectrometer, geocorona H Lyman-alpha telescope, and solar X-ray detector.

Project Results – OSO IV was launched on October 18, 1967 from Cape Kennedy into an orbit of 338 to 358 miles at 33° inclination. Completed 1118 orbits as of Dec. 31. All experiments have returned useful data. Ultraviolet spectrometer data sent directly from spacecraft to experimenter, and were first pictures made of sun in extreme ultraviolet.

Major Participants – NASA Goddard Space Flight Center, spacecraft, launch vehicle, and experiment management; Ball Brothers Research Corp., spacecraft prime contractor; American Science and Engineering Inc., Harvard College Observatory, Lawrence Radiation Laboratory (Univ. of California), U.S. Naval Research Laboratory, Univ. College London, Univ. of Leicester, experimenters; McDonnell Douglas, launch vehicle prime contractor.



OSO-IV SPECTROHELIOGRAMS
HARVARD COLLEGE OBSERVATORY

The Sun, the Earth's mother star, produced these pictures from observations made by Orbiting Solar Observatory-IV, as compared to image obtained by Sacramento Peak Observatory (upper left).

Key Spacecraft Personnel		Affiliation
PM	L. Hogarth	NASA-GSFC
PS	W.E. Behring	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
1-20A, 44-75A, Solar X-Ray Detector	PI	R. L. F. Boyd	University College, London
	OI	E. A. Stewardson	Unknown
	OI	K. A. Pounds	University of Leicester
Extrasolar X-Ray Detector	PI	R. Giacconi	Harvard College Observatory
	OI	H. Gursky	Harvard College Observatory
304A, HE II Monochromator	PI	R. L. F. Boyd	University College, London
Proton-Electron Telescope	PI	J. A. Waggoner	Lawrence Livermore University
Geocor. Hydrog. Lyman-Alpha Telescope	PI	R. W. Kreplin	U.S. Naval Research Laboratory
	OI	T. A. Chubb	U.S. Naval Research Laboratory
	OI	P. W. Manage	U.S. Naval Research Laboratory
	OI	H. D. Friedman	U.S. Naval Research Laboratory
Solar X-Ray Detector	PI	T. A. Chubb	U.S. Naval Research Laboratory
	OI	R. W. Kreplin	U.S. Naval Research Laboratory
	OI	H. D. Friedman	U.S. Naval Research Laboratory
300-1400 EUV Spectrometer	PI	L. Goldberg	Harvard College Observatory
	OI	E. M. Reeves	Harvard College Observatory
	OI	W. H. Parkinson	Harvard College Observatory
Solar X-Ray Telescope	PI	R. Giaccconi	Harvard College Observatory
	OI	A. S. Krieger	AS+E, Inc.
	OI	F. R. Paolini	AS+E, Inc.
Solar X-Ray Spectrometer, 1-8A	PI	H. D. Friedman	U.S. Naval Research Laboratory
	OI	T. A. Chubb	U.S. Naval Research Laboratory
	OI	R. W. Kreplin	U.S. Naval Research Laboratory
	OI	J. F. Meekins	U.S. Naval Research Laboratory

ATS III

Launch Vehicle – Atlas-Agena D: 388,340-pound-thrust Atlas first stage, 16,000-pound-thrust Agena D second stage. First stage radio guided, second stage inertially guided. Height: 109 feet.

Spacecraft Description – Cylindrical, 6 feet long and 5 feet in diameter, with sides covered by solar cells except for camera opening. Forward panel supported sun sensors, axial jets, and eight 5-foot-long VHF experiment whip antennas mounted around forward end. Thrust tube extends from aft end and contains apogee kick motor. Weight (after apogee motor burnout): 805 pounds.

Project Objectives – Further development of experiments and concepts in the useful applications of space technology to communications, meteorology, navigation, and earth resources management.

Spacecraft Payload – Nine major experiments: color Spin-Scan Cloud Camera (SSCC), intended to produce high-resolution (2.2 miles at picture center) color photos of full disk of earth, and consisting of a high-resolution telescope, three photomultiplier light detectors, a multiplexer, and a precision latitude step mechanism. SSCC designed to make use of spacecraft spin to provide line scan of 2400 lines per picture. Also tested in space for the first time was an Image Dissector Camera (IDC) which, instead of mechanical scanning, employed electronic scanning to produce black-and-white meteorological pictures of more than 40 million square miles coverage with resolution of about 4.5 miles at picture center. IDC was expected to be more suitable for less stable, spinning platforms, in that it can repeat scan lines immediately rather than mechanically continue line-by-line scans, thereby correcting itself should one or more of the 1328 lines per picture be garbled. In addition to cameras, ATS III carried an Omega Position Location Equipment (OPLE) experiment to demonstrate for the first time the feasibility of locating platforms and collecting data on a global basis employing the Navy's Omega navigation system. The on-board OPLE package consisted of a VLF and VHF receiver, decoder, memory system, timing equipment, battery, and a 3-foot, X-shaped dipole antenna. A Weather Facsimile (WEFAX) experiment involved transmitting weather data in facsimile format from the ATS Mojave ground station to the spacecraft, then relaying the data to special ground stations within communications range. In addition, selected SSCC pictures were to be transmitted via the satellite to Automatic Picture Transmission (APT) ground readout stations. Purpose of WEFAX experiment: test satellite transmission of facsimile products and explore feasibility of increasing amount of data available to stations equipped for receiving APT

photos from ESSA and Nimbus satellites. Communications experiments, to be conducted with the two microwave repeaters comprising ATS III's super high frequency communications subsystem, involved multiple access mode tests to evaluate the single side band technique for multiple-access communications; and frequency translation mode tests to evaluate a high quality FM system for relaying wideband data such as color television, telegraph, and digital and facsimile data. Other communications experiments were to be conducted to evaluate a VHF repeater and its antenna system as a relay for two-way voice communications between ground stations and in-flight aircraft. Technology experiments included the Self-Contained Navigation System (SCNS), mechanically despun antenna, reflectometer, and resisto jet. The SCNS, essentially a star-scanning system, consisted of an optics subsystem (sun-shade, lens, slits, reflector, photomultiplier tube), electronics subsystem (filters, amplifiers, command electronics), and ball ejection system (three 3-inch hollow, white, stainless steel spheres, together with spring-loaded ejectors and ball firing mechanism). Objectives of the SCNS: determine spacecraft attitude using the optical star scanning system to measure star transit times through the slits; determine spacecraft position as a function of time by sighting on an ejected sphere against the star background; and determine spacecraft position as a function of time by taking sightings of the moon. Mechanically despun antenna, a unidirectional antenna system consisting of a rotating cylindrical parabolic collimator, utilized a stepping motor driven at a rate synchronous with spacecraft spin but of opposite direction so as to de-spin (stop) the antenna beam, thus providing higher antenna gain. Reflectometer experiment, intended to measure reflectance degradation of specularly reflective surface samples in the space environment, utilized pairs of test samples, with one of each pair shielded by clear quartz. Resisto jet experiment, a pressure-regulated liquid ammonia electrothermal thruster system incorporating two fast-heat-up resisto jet engines, was intended to determine operating characteristics of such a system by measuring spin reduction of the spacecraft as a result of thrust engine firings. In addition to on-board experiments, ATS III was to be used for making several ground test experiments involving orbital evaluation, range and range rate at microwave frequencies, ranging at VHF, calibration of the Space Tracking and Data Acquisition Network, navigation studies, propagation studies, timing experiments, geodetic studies, and ground stations evaluation. ATS III employed three types of reaction control subsystems: a cold gas 75-pound-thrust nitrogen subsystem for spinning up the spacecraft at separation to the required 90 rpm, a hydrogen peroxide subsystem, and a hydrazine subsystem – the latter two at 5 pounds thrust each. One of the latter two subsystems was to be used to increase spin rpm to 100, and both were to be used for longitudinal positioning, orbital inclination, and eccentricity adjustments. Redundant command subsystem consisted of two 148.26 mHz receivers, two decoders, and two regulators, with receivers and decoders cross-strapped so that each receiver could operate with each decoder. Telemetry subsystem incorporated two transmitters operating at 136.47 and 137.35 mHz, two encoders, signal conditioning units, and two regulators, with the two transmitters and two encoders cross-strapped. Power system utilized solar panels and 12-watt TWT's providing ERP of one kilowatt. Passive thermal control.

Project Results – ATS III was launched on November 5, 1967 from Cape Kennedy into a synchronous equatorial orbit of 22,228/22,254 miles. First color photos of earth from synchronous orbit were received on November 8, 1967. Spacecraft was moved from initial position of 45° to 95° in order to provide better views of U.S. during storm season, and returned to original position in the spring. All systems except SCNS have returned useful data.

Major Participants – NASA Goddard Space Flight Center, spacecraft management; Hughes, spacecraft prime contractor; Avco, Control Data, EOS, General Dynamics, ITT, Philco-Ford, Rantec, Raytheon, RCA, Sylvania, Westinghouse, experimenters; General Dynamics, first stage prime contractor; Lockheed, second stage prime contractor.

Key Spacecraft Personnel		Affiliation
PM	R.J. Darcey	NASA-GSFC
PS	T.L. Aggson	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Spin Scan Cloud Camera	PI	V. E. Suomi	University of Wisconsin
	OI	R. S. Parent	University of Wisconsin
Ions Propagation Experiment	PI	A. V. Darosa	Stanford University
Image Dissector Camera	PI	G. A. Branchflower	NASA-GSFC
Communications Microwave Transponder	PI	Unknown	Unknown
60MM VHF Radio Transponder	PI	Unknown	Unknown
Self-Contained Navigation Experiment	PI	Unknown	Unknown
Reflectometer Experiment	PI	Unknown	Unknown
Hydrazine Thruster	PI	Unknown	Unknown
Resisto-Jet Thruster	PI	Unknown	Unknown
Meteorological Data Relay System	PI	D. W. Holmes	NOAA-NESS
	OI	S. Wishna	NASA-GSFC
Omega Position and Location	PI	C. R. Laughlin	NASA-GSFC
	OI	G. E. Hilton	NASA-GSFC

SURVEYOR VI

Launch Vehicle – Same as that for Surveyor V.

Spacecraft Description – Same as that for Surveyor V.

Project Objectives – Further development of lunar soft-landing technology and provision of data in support of Apollo. Primary objectives of this mission: soft-land in 27-mile diameter circle near center of front face of moon, in Sinus Medii at 0.42°N and 1.33°W (the last area of primary interest as Apollo landing site); return television photos of lunar surface, data on chemical characteristics of lunar soil.

Spacecraft Payload – Same as that for Surveyor V, except for new square hood on camera to protect reflecting mirror mounted in camera turret from stray light reflections.

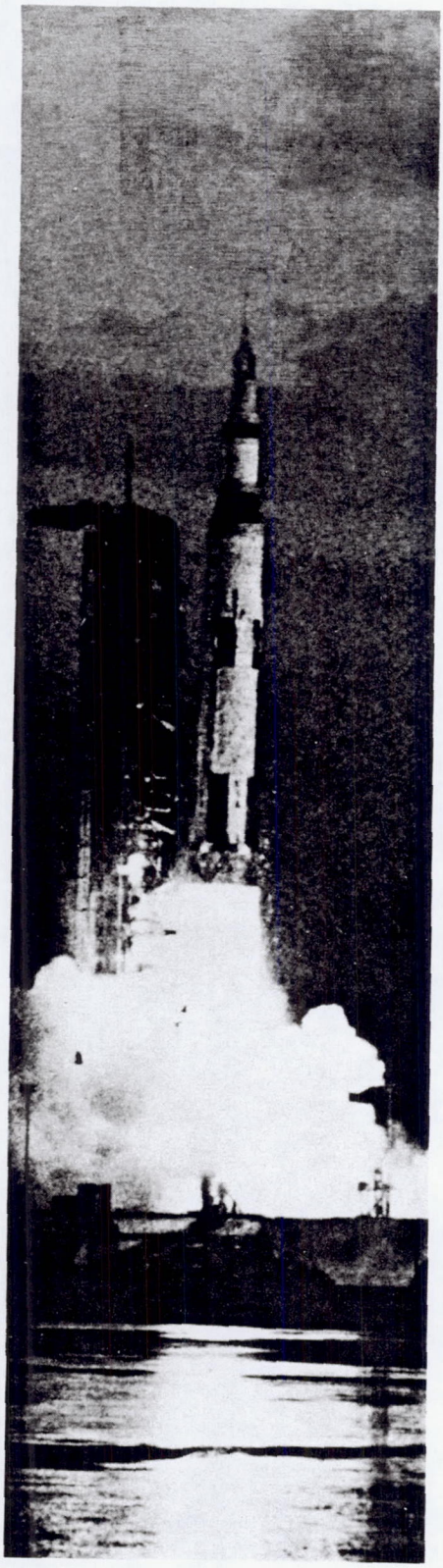
Project Results – Surveyor VI was launched on November 7, 1967 from Cape Kennedy. After coasting briefly in parking orbit, Centaur second stage injected spacecraft into lunar transfer trajectory. Successful soft landing at 0.47°N and 1.48°W, a site within 4 miles of midcourse target, was achieved 65 hours after liftoff. Pictures and soil analysis data were transmitted as planned; then, on a signal from earth, the three vernier engines were restarted, lifting spacecraft 10 feet from surface and landing again 8 feet from original site, thereby performing the first rocket-powered takeoff from lunar surface.

Major Participants – JPL, spacecraft management, tracking; Hughes, spacecraft prime contractor; Ryan, radar altimeter and doppler velocity sensor; Thiokol, retro and vernier propulsion; Cal Tech and U.S. Geological Survey, University of Chicago experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PS	L. D. Jaffe	NASA-JPL

Experiment	Experiment Personnel		Affiliation
Television Experiment	PI	E. M. Shoemaker	California Institute of Technology
	OI	R. M. Batson	U.S. Geological Survey
	OI	R. A. Altenhofen	U.S. Geological Survey
Alpha Scatter	PI	A. L. Turkevich	University of Chicago
	OI	E. J. Franzgrote	NASA-JPL
Surface Mechanics	PI	R. F. Scott	California Institute of Technology
	OI	R. M. Haythornwaite	Pennsylvania State University
Hard. of Surface	PI	S. A. Batterson	NASA-LARC
Seismic Data	PI	G. H. Sutton	University of Hawaii
	OI	W. M. Ewing	Unknown
	OI	F. Press	Massachusetts Institute of Technology
Lunar Experiment	PI	J. L. Bohn	Temple University
	OI	W. M. Alexander	Baylor University

APOLLO IV



Launch Vehicle – Saturn V: S-1C first stage consisted of five F-1 engines at 1,514,000 pounds of thrust each for a total first stage thrust of over 7,500,000 pounds; S-II second stage consisted of five J-2 engines at 200,000 pounds of thrust each for a total second stage thrust of 1,000,000 pounds; S-IVB third stage consisted of a single J-2 engine at 200,000 pounds of thrust. All three stages inertially guided. Saturn V Instrument Unit, a cylinder 3 feet high and 21 feet 8 inches in diameter mounted atop third stage, contained vehicle electronics for navigation, guidance and control, measurement of vehicle performance and environment, telemetry and command reception, checkout and monitoring of vehicle functions, power generation and distribution, and preflight checkout, launch, and flight operations. Height: 363 feet.

Spacecraft Description – Block I (earth-orbit type) Command Module, Service Module, Spacecraft Lunar Module Adapter, and Lunar Module Test Article. The Command Module, a cone 12 feet high with base diameter of 12 feet 10 inches and habitable volume of 210 cubic feet, had an outer structure (heat shield) of stainless steel honeycomb bonded between steel alloy sheets, with surface application of phenolic epoxy resin ablative material. Inner structure of aluminum honeycomb between aluminum alloy with sandwich thickness from ¼ inch at forward access tunnel to 1½ inches at base. Outer and inner structures separated by fibrous insulation and support stringers. A total of 12 attitude control jets located on exterior of Command Module, two each for pitch, roll, and yaw on base and conical sides. Weight of Command Module at launch: 12,000 pounds. Service Module, the top of which joined to and supported the Command Module, was a cylinder 12 feet 10 inches in diameter and 22 feet in length, including an extension to service propulsion system (SPS) engine. Structure was aluminum honeycomb outer skin 1 inch thick, formed by six panels bolted to solid aluminum structural uprights. Interior, divided into wedge-shaped compartments around center cylindrical section, contained auxiliary equipment, SPS fuel tanks, SPS oxidizer tanks, and helium tanks for SPS pressurization. Space radiators to dissipate heat from electrical power system and environmental control system located externally on four of the six service module panels (but left unconnected for Apollo IV mission). Four reaction control system packages spaced equidistant around circumference of Service Module. Weight of Service Module at launch: 55,000 pounds. Spacecraft Lunar Modular Adapter, a tapered cylindrical shape 28 feet high, 12 feet 10 inches in diameter at top supporting Service Module, and 22 feet in diameter at base joined to S-IVB third stage, housed 29,500-pound Lunar Module Test Article ("boilerplate" version of Lunar Module), which remained attached to S-IVB third stage. Weight of adapter: 3900 pounds. Total weight placed in initial orbit: 278,699 pounds.

Apollo IV, first launch of a Saturn V vehicle, also tested Apollo heat shield.

Project Objectives – Obtain flight information on launch vehicle/spacecraft structural integrity and compatibility, on flight loads, stage separation, and subsystem operation; evaluate Command Module heat shield under re-entry conditions to be encountered on return from lunar mission. Test flexible thermal seals to be used in new outward-opening quick-release hatch for Command Module. Flight plan called for placing spacecraft and S-IVB third stage into 117-mile circular orbit at 32.73° inclination. After completing two orbits, third stage was to ignite a second time, raising apogee to 10,800 miles, followed by separation and SPS engine firing to raise apogee to 11,400 miles. Following cold soak, second SPS burn was to raise re-entry velocity to 25,000 mph before separation of Command and Service Modules.

Spacecraft Payload – Command Module contained an Apollo mission programmer for spacecraft subsystem operation in the absence of a crew, an instrumented test panel in place of hatch window to test flexible thermal seals and gaps between hatch and surrounding heat shield, and a color camera. Service Module reaction control system featured four independent subsystems, each subsystem containing four hypergolic-fueled 100-pound-thrust engines. Command Module reaction control system comprised two (redundant) independent subsystems of six hypergolic-fueled 93-pound-thrust engines each. Thrust for major velocity changes – and (in earth-orbit missions) for de-orbit burn to achieve re-entry – provided by 21,500-pound-thrust hypergolic-fueled SPS engine. Stabilization and control provided by three identical attitude gyros mounted along spacecraft body axes, three rate gyros, pendulous attitude gyro accelerometer, attitude set and gimbal position indicators, velocity change indicator, and electronic processing and signal conditioning equipment. Guidance and navigation provided by ST-124M inertial platform, guidance computer, and two display and keyboard panels. Electrical power provided by zinc-silver oxide batteries and hydrogen-oxygen fuel cells together with associated DC converters and power distribution equipment. Environmental control system consisted of water and glycol circulating systems. Telecommunications provided by data processing equipment including signal-conditioning, data storage, central timing, up data digital decoding, pulse-code modulation, and premodulation processing equipment; RF electronics equipment including VHF/FM transmitter and VHF/AM transceiver, C-band transponder, unified S-band equipment, VHF recovery beacon, and HF transceiver; and associated VHF omnidirectional, S-band, VHF recovery, HF recovery, and C-band antennas. Parachute subsystem included two 13.7-foot-diameter conical nylon drogue chutes, three 7.2-foot-diameter nylon pilot chutes, and three 83.5-foot-diameter nylon main chutes. Spacecraft recovery facilitated by compressor-inflated bags to achieve upright position in water, fluorescent sea dye marker with 12-hour capacity, flashing beacon on command module apex, VHF

recovery beacon transmitter, and swimmer's umbilical. Mission abort capability provided from pre-liftoff through T+173 seconds (above 270,000 feet) in any one of three phases: pad, low altitude, and high altitude. Launch escape system, 33 feet tall with base diameter of 4 feet, included three solid-propellant motors – one for tower jettison, one for pulling spacecraft up and out from launch vehicle, and one for pitch control – and a boost protective cover over apex of Command Module for protection against boost heating and rocket exhaust of launch escape motor. Launch escape system jettisoned shortly after second stage ignition. Earth landing under abort conditions employed parachute system essentially the same as in normal re-entry descent.

Project Results – Apollo IV was launched from Cape Kennedy on November 9, 1967 into a 119/114-mile orbit at 32.6° inclination. During third orbit, S-IVB third stage was re-ignited, lifting entire combination to height of 10,969 miles before S-IVB separation. First burn of SPS raised spacecraft to apogee of 11,240 miles. At end of 4½-hour cold soak, second SPS burn increased speed to 25,120 fps. Service Module was jettisoned, and Command Module re-entered atmosphere at 36,537 fps, with heat shield withstanding temperature of 5051°F. Command Module landed about 6 miles from target landing point 8 hours, 37 minutes after liftoff, was recovered by U.S.S. Bennington. Performance of all systems was near nominal; entire mission regarded as success.

Major Participants – NASA Office of Manned Space Flight Center, program management; NASA Manned Spacecraft Center, spacecraft management; NASA Goddard Space Flight Center, tracking and data acquisition; NASA Kennedy Space Center, launch operations; North American Rockwell, spacecraft prime contractor, Command and Service Modules; Grumman, Lunar Module; NASA Marshall Space Flight Center, launch vehicle; Boeing, first stage prime contractor; North American Rockwell, second stage prime contractor; McDonnell Douglas, third stage prime contractor; IBM, Saturn V instrument Unit.

ESSA VI

Launch Vehicle – Thrust Augmented Improved Delta: modified Thor first stage at 172,000 pounds of thrust, augmented by three first stage strap-on solid-propellant Castor I rockets for a combined total first stage thrust of 333,500 pounds; 7700-pound-thrust second stage; 5600-pound-thrust FW4 solid-propellant third stage. Height: 92 feet.

Spacecraft Description – Standard Tiros-ESSA configuration: hatbox-shaped 18-sided polygon, 22 inches high and 42 inches in diameter, covered by 9100 solar cells. Single 18-inch receiving antenna projected from top, four 22-inch transmitting whip antennas extended from bottom. Two 1-inch Automatic Picture Transmission (APT) cameras, similar to those tested on Tiros VIII and Nimbus I and II and used operationally in ESSA II and ESSA IV, mounted on each side 180° apart. Spin stabilized at 10 rpm. Weight: 290 pounds.

Project Objectives – The system, financed by ESSA and managed and operated by ESSA's National Environmental Satellite Center, provided both global and local cloud-cover pictures every day. The system, based upon Tiros technology, began operating in February of 1966 with the launching of ESSA I and ESSA II. Pictures taken by ESSA I, ESSA III, and ESSA V were stored for transmission to ESSA's two command and data acquisition stations, and used in central analysis of global weather. A total of 305 receiving stations were in operation around the world – including 89 in other nations. Weather services of 45 foreign countries – as well as 26 universities, 25 to 30 U.S. television stations, and an undetermined number of private citizens who have built their own receivers – received and used the photographs every day.

ESSA V was intended to replace ESSA II and ESSA IV. Due to a slow orbital drift, ESSA II cameras were viewing scenes under low-level early morning illumination. ESSA IV which had exceeded specified operational lifetime, was operating with only one camera.

Spacecraft Payload – Camera system similar to that used on ESSA IV: two 1-inch APT cameras capable of photographing areas of about 2000 miles on a side with two-mile resolution at picture center. APT system designed to take and transmit a picture every 352 seconds, allowing a typical APT station to receive 8-10 pictures every day. On-board triggering system programmed cameras to take pictures only when facing earth. Position and spin stabilization maintained by magnetic attitude coils. Powered by nickel-cadmium batteries and 9100 n/p solar cells.

Project Results – ESSA VI was launched on November 10, 1967 from Vandenberg AFB into a retrograde, sun-synchronous orbit ranging from 876 to 925 miles at 102° inclination.

Major Participants – ESSA, project management; NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.

PIONEER VIII TEST AND TRAINING SATELLITE - I (TTS I/TETR I/ TATS I)

Launch Vehicle – Thrust Augmented Delta (TAD): Thor first stage with three strap-on solid-propellant motors and total thrust of 333,500 pounds, 7800-pound-thrust second stage, and 5750-pound-thrust solid-propellant third stage. First and second stages radio guided, third stage spin stabilized. Height: 92 feet.

Spacecraft Descriptions – Pioneer VIII employed same basic spacecraft design as Pioneers VI and VII: cylinder 37 inches in diameter and 35 inches high. Fifty-two inch mast containing high-gain and two low-gain antennas projected from one end, dual-frequency antenna used in radio propagation experiment deployed from the other. Wobble damper, magnetometer, and orientation nozzle separately extended from midsection at ends of 64-inch booms. Spacecraft structure primarily aluminum; sides of cylinder covered with solar cells except for experiment view band at midsection. Spin stabilized at 60 rpm. Weight: 145 pounds. Test and Training Satellite I (TTSI): octahedral Environmental Research Satellite (ERS), 12 inches across each side, each triangular side bearing 111 solar cells. Three VHF antennas (Receiver monopole, transmitter dipole) stored as coils during launch and deployed following separation. Fourth antenna, located 180° from the receiver monopole, operates on S-band. Weight: 44 pounds.

Project Objectives – Pioneer VIII: third in series of interplanetary probes designed to provide data on solar wind, magnetic fields, and cosmic rays, Pioneer VIII was intended to seek a clear definition of tail of earth's magnetosphere as well as to monitor solar events as the sun reaches climax of its 11-year-cycle in 1969. Like Pioneer VII intended to fly an "out" mission in the plane of earth's orbit. TTS I: provided economical means of testing and training Apollo unified S-band ground stations and shipboard crews in spacecraft acquisition and telemetry reception.

Spacecraft Payload – Pioneer VIII: two of the seven experiments carried were new, five represented major improvements over those on Pioneer VII. Magnetometer experiment capable of switching to a high field range during solar storms. Cosmic ray detector able to identify incoming nuclei of chemical elements heavier than hydrogen; measure incoming hydrogen nuclei at speeds up to 90% of the speed of light; observe galactic particles arriving from above and below the plane of earth's orbit. Range of radio propagation experiment increased from 110 million to 200 million miles. Solar wind experiment 10 times more accurate than its predecessors. New experiments were an interplanetary dust collector and an instrument to study electric fields in space. TTS I: S-band transponder, receiving frequency 2101.9 mHz, transmitting frequency 2282.5 mHz. Magnetically stabilized. Power system consisted of solar cells and rechargeable battery; maximum output: 5 watts.

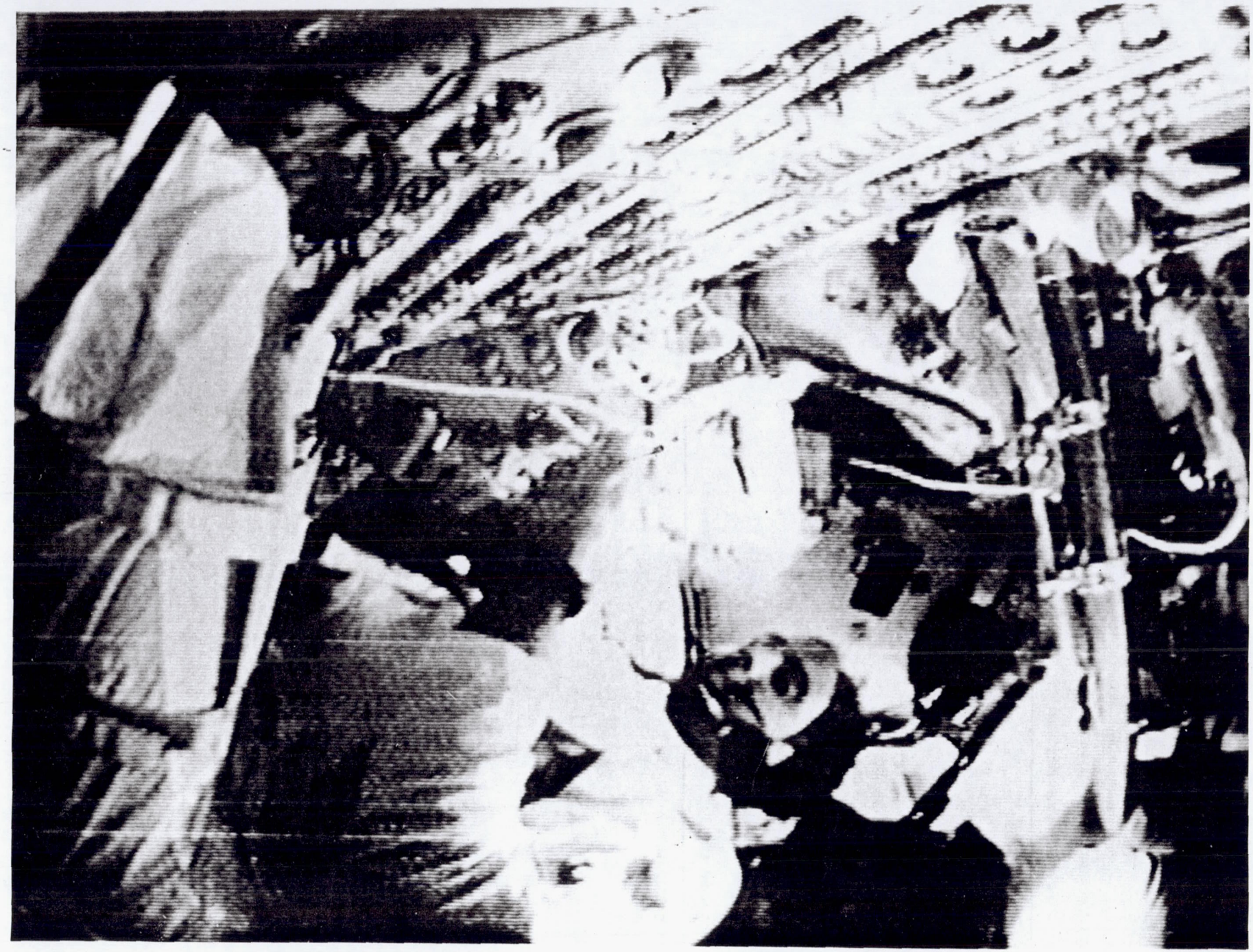
Project Results – Pioneer VIII was launched from Cape Kennedy on December 13, 1967. After 22 minutes in a 191/373-mile parking orbit, the Delta third stage injected the spacecraft into solar orbit. Operational status: excellent. TTS I, the first NASA piggyback payload, was launched together

with Pioneer VIII and spring-ejected from a cannister mounted on the Delta second stage into a 187/303-mile orbit at 33°.

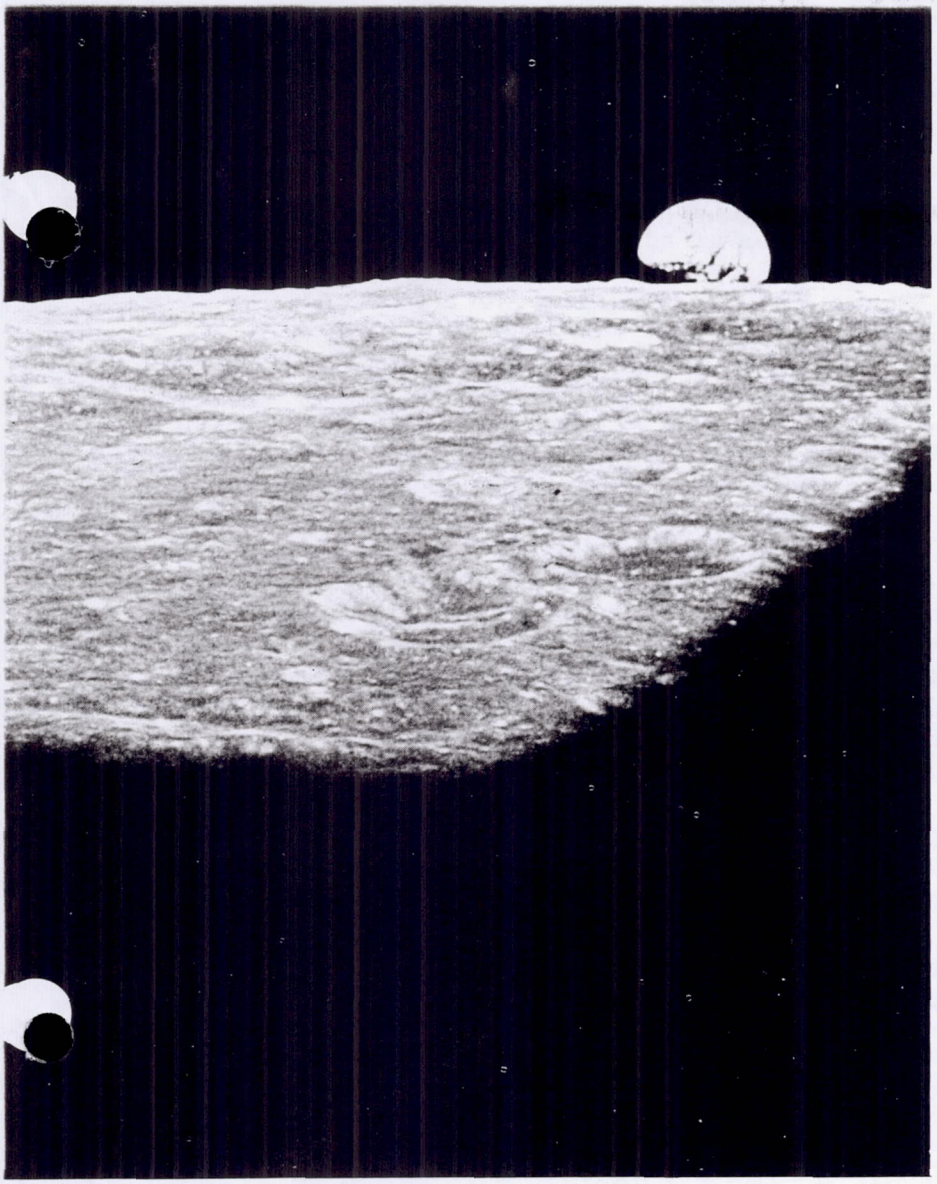
Major Participants – NASA Ames Research Center, Pioneer VIII spacecraft management, experimenter; TRW, Pioneer VIII spacecraft prime contractor, TTS I spacecraft prime contractor, experimenter; NASA Goddard Space Flight Center, TTS I spacecraft management, experimenter; Southwest Center for Advanced Research, Univ. of Minnesota, Stanford Univ., experimenters; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
Pioneer VIII		
PM	C.F. Hall	NASA-ARC
PS	J.H. Wolfe	NASA-ARC
CO	N.J. Martin	NASA-ARC
CO	N.A. Renzetti	NASA-JPL
CO	A.J. Siegmeth	NASA-JPL
MG	F.D. Kochendorfer	NASA Headquarters
SC	A.G. Opp	NASA Headquarters
TTS I		
PM	C.H. Underwood	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Single Axis Magnetometer	PI	N.F. Ness	NASA-GSFC
	OI	S.C. Cantarano	CNR, Space Plasma Laboratory
	OI	F. Mariani	University of Rome
Electrostatic Analyzer	PI	J.H. Wolfe	NASA-ARC
	OI	D.D. McKibbin	NASA-ARC
Two Frequency Beacon	PI	V.R. Eshleman	Stanford University
	OI	T.A. Croft	SRI International
	OI	H.T. Howard	Stanford University
	OI	R.L. Leadabrand	SRI International
	OI	R.A. Long	SRI International
	OI	A.M. Peterson	Stanford University
Cosmic Dust Detector	PI	O.E. Berg	NASA-GSFC
	OI	L. Secretan	NASA-GSFC
Cosmic Ray Anisotropy	PI	K.G. McCracken	CSIRO
	OI	U.R. Rao	ISRO Satellite Center
	OI	W.C. Bartley	National Academy of Sciences
Cosmic Ray Gradient Detector	PI	W. R. Webber	University of New Hampshire
Electric Field Detector	PI	F.L. Scarf	TRW Systems Group
	OI	I.M. Green	TRW Systems Group
Celestial Mechanics	PI	J.D. Anderson	NASA-JPL



1968





Photographs from the successful Apollo VIII lunar-orbital mission. Left, televised picture of spacecraft interior showing lunar pilot astronaut William A. Anders. Top, a new look at an old planet: "Earth rise" as seen during the flight. Bottom right, a safe return of the Apollo VIII crew. Recovery helicopter from aircraft carrier U.S.S. Yorktown picks up one of the astronauts.

SURVEYOR VII

Launch Vehicle – Atlas-Centaur: 395,340-pound-thrust Atlas SLV-3C first stage, 30,000-pound-thrust Centaur second stage. First stage radio guided, second stage inertially guided. Height: 117 feet.

Spacecraft Description – Same as previous Surveyors: a triangular framework constructed of thin-wall tubular aluminum which provided mounting surfaces and attachment points for landing gear, main retrorocket engine, vernier engines, and associated tanks, thermal compartments, and other assemblies. A mast mounted in the center of the triangle supported the planar array high-gain antenna and a single solar panel 30 by 44 inches. Basic frame weighed less than 60 pounds, installation hardware weighed 23 pounds. A tripod landing gear was attached by hinges to the three lower corners of the frame and was folded upright during launch. A crushable aluminum honeycomb footpad was attached to the outer end of each leg. Two omnidirectional, conical antennas were mounted on ends of folding booms which were hinged to the frame. Spacecraft stood about 10 feet high and, with landing gear extended, could be placed within a 14-foot circle. Weight at launch: 2288 pounds; landing weight: about 625 pounds.

Project Objectives – Soft-land within 12.4-mile-diameter circle north of the crater Tycho at 40.87°S and 11.37°W – a site as geologically different as possible from previous sites. All Surveyor objectives in support of Apollo having been achieved by Surveyors I, III, V, and VI, which investigated four widely separated regions in ancient seas along the moon's equatorial zone, Surveyor VII was aimed at a site of primarily scientific interest. Obtain photos, radar reflectivity data, and thermal data; conduct digging, trenching, and bearing strength tests; perform on-site magnetic test and chemical analysis of lunar soil.

Spacecraft Payload – Television camera, magnet, surface scoop sampler, and alpha-scattering experiment. The scoop and the alpha experiment, carried for the first time on the same mission, were to be operated as a team: the alpha experiment was to be conducted over material exposed by the scoop, and the scoop was to be used to reposition the alpha experiment. Camera, capable of providing 200- or 600-line pictures, was mounted vertically on crossbar near top of spaceframe and pointed at mirror which could swivel 360°, tilt up to view above the horizon, or tilt down to view a leg of the spaceframe. A total of 11 mirrors located throughout the spacecraft to permit additonal access viewing. A small magnetic bar 2 inches x 1/2 inch x 1/8 inch made of iron-nickel-cobalt-aluminum alloy, together with a nonmagnetic control bar made of iron-nickel-cobalt alloy, was mounted on footpads 2 and 3. (Surveyors IV, V and VI carried only one magnetic bar and control bar.) Two smaller u-shaped magnets were also added, and were mounted on underside of scoop door of surface sampler. Visual comparison of magnetic and control bars, which were mounted in view of camera, permitted determination of presence of magnetic particles. Surface scoop sampler was similar to that carried aboard Surveyors III and IV, except for the two u-shaped magnets installed in scoop door. The scoop, about 5 inches

long and 2 inches wide, was attached to an extendable arm hinged horizontally and vertically to the spaceframe. The arm, made of tubular aluminum cross members which operated in scissor fashion, was spring-loaded to about 5 feet and retractable via a motor-wound metal tape. Two other motors pivoted the arm horizontally 112° and vertically from 40 inches above to about 18 inches below lunar surface. The 2- x 4-inch scoop door was operated by a fourth motor. Surface area available to sampler totalled about 24 square feet. Alpha-scattering experiment, like those previously carried aboard Surveyors V and VI, consisted of sensor head, instrument electronics and auxiliary, deployment mechanism, thermal compartment, thermal control and heater assembly, and wiring harnesses and attachment hardware. Sensor unit, a gold-plated aluminum box containing curium 242 and alpha and proton detectors, was lowered by a nylon cord and a wheel and rachet assembly and could be repositioned on the lunar surface by the arm-and-claw mechanism of the surface sampler. Electronics unit contained logic circuitry to measure pulsewidth and put the data into binary words; binary words (both alpha and proton events) then applied to subcarrier oscillators contained in electronics auxiliary. Subcarrier oscillator outputs routed to central signal processor for final summing prior to transmission. Engineering instrumentation included auxiliary processor, extra temperature sensors, strain gauges and accelerometers for measuring vernier engine response to flight control commands and shock absorber loading at touchdown, and accelerometers for measuring structural vibration during main retro burn. Telecommunications provided by one high-gain directional and two low-gain omnidirectional antennas, two transmitters, and two receivers with transponder connections; command decoders; and signal processors. Propulsion system consisted of three liquid-fuel vernier engines for midcourse correction and terminal descent, and a solid-fuel retrorocket for the major portion of deceleration during lunar landing. Flight control provided by a primary sun sensor, automatic sun acquisition sensor, Canopus star sensor, inertial reference unit, altitude marking radar, inertia burnout switch, radar altimeter and Doppler velocity sensors, flight control electronics, and three pairs of cold gas jets. Electrical power provided by 3960 solar cells arranged on a honeycomb substrate approximately 9 feet square mounted at top of spacecraft mast and a 14-cell silver-zinc battery. Thermal control for sensitive electronics equipment provided by three thermal compartments insulated with 75 sheets of aluminized Mylar, covering with mirrored glass, and containing heater assemblies powered by main battery. Thermal control for less sensitive equipment achieved by paint patterns and polished surfaces.

Project Results – Surveyor VII was launched from Cape Kennedy on January 7, 1968. After coasting 22.5 minutes in parking orbit, Centaur second stage injected spacecraft into lunar transfer trajectory. A minimum midcourse correction was sufficient to reach the target on the northern flank of the Tycho rim. Successful soft landing was achieved 66.5 hours after liftoff at 40.89°S and 11.4°W. Photo transmission began 41 minutes after landing, provided pictures of lunar terrain, portions of the spacecraft, experiment operations, stars, planets, crescent earth as it changed phases, and the first observation of artificial light from earth as laser beams were directed from Kitt Peak Observatory in Arizona and JPL's Table Mountain Observatory in

California. Over 21,000 high-resolution photos were received. Difficulty was encountered with alpha-scattering experiment when sensor unit failed to be fully lowered to lunar surface; surface sampler was used to manipulate the unit downward, and chemical analysis was successfully performed at three different sites near the spacecraft. Chemical analyses indicated that lunar soil at this site once had been in a molten state. Photos showed debris ejected from Tycho and sequence of molten flows. Magnet experiment revealed lower content of iron and heavy elements, indicating that highlands material is lighter than that found in the marias. One rock fragment was "weighed" by picking it up in the scoop and comparing motor current readings with readings taken while scoop was empty. Rock fragment was then held before one of the mirrors to obtain visual estimate of volume. Weight and volume estimates permitted estimate of density. First lunar day operations were concluded on January 23, 1968.

Major Participants – JPL, spacecraft management, tracking; Hughes, spacecraft prime contractor; Ryan, radar altimeter and doppler velocity sensor; Thiokol, retro and vernier propulsion; Cal Tech, University of Chicago, U.S. Geological Survey, experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics, launch vehicle prime contractor.

	Key Spacecraft Personnel	Affiliation
PM	W. Eugene Giberson/Robert J. Parks/ Howard H. Haglund	JPL JPL
PS	Leonard L. Jaffe	JPL
MG	Benjamin Milwitzky	

Experiment	Experiment Personnel		Affiliation
Surface Sampler - Photo	PI	E.M. Shoemaker	California Institute of Technology
	OI	R.M. Batson	US Geological Survey
Mechanical Surface Sampler	PI	R.F. Scott	California Institute of Technology
	OI	R.M. Haythornwaite	Pennsylvania State University
Alpha Scatterometer Surface Analyzer	PI	A.L. Turkevich	University of Chicago
Hard. of Surface	PI	S.A. Batterson	NASA-LARC
Seismic Experiments	PI	G.H. Sutton	University of Hawaii
	OI	W.M. Ewing	Unknown
	OI	F. Press	Massachusetts Institute of Technology
Lunar Ejecta	PI	J.L. Bohn	Temple University
	OI	W.M. Alexander	Baylor University

EXPLORER XXXVI
(GEOS - II)

Launch Vehicle – Thrust Augmented Delta: Thor first stage with three strap-on solid-propellant motors and total thrust of 333,550 pounds, 7700-pound-thrust second stage, and 5600-pound-thrust FW-4 solid-propellant third stage. First and second stages radio guided, third stage spin stabilized. Height: 92 feet.

Spacecraft Description – Octagon aluminum shell with eight-sided truncated pyramid on top, 48 inches across flats and 32 inches high. A 24-inch fiberglass hemisphere with broadband spiral antenna paint pattern projected from satellite's base. Extendable 60-foot gravity gradient boom of silver-plated beryllium-copper mounted on top, with eddy current damper on end of boom. Eight trapezoidal panels formed the base surface and encircled the fiberglass hemisphere. Mounted on four of the panels were four optical sensor flashing light assemblies, laser detector, and a 4-inch-high conical antenna. The remaining four panels contained arrays of quartz prisms. Solar cells covered spacecraft exterior except for base. Weight: 460 pounds.

Project Objectives – Provide more precise information about the size and shape of the earth (geometric geodesy) and the strength of and variations in the earth's gravitational field (gravimetric geodesy) by establishing the location of a set of worldwide tracking stations whose positions are known with an accuracy of 33 feet or better. Secondary objectives included improving positional accuracies of satellite tracking sites and calibration of tracking equipment, comparing and correlating results obtained from various geodetic systems on the spacecraft, and calibrating the ranging accuracy of specific ground-based radars for their evaluation as geodetic instrumentation systems.

Spacecraft Payload – Six geodetic systems: optical beacon system, comprising four xenon flash tubes emitting a combined candlepower of 6620 candles-seconds per flash, to be photographed against a background of stars; radio doppler system, consisting of three transmitters operating at 162-, 324-, and 972-mHz and an ultra-stable oscillator, for determining the line-of sight velocity of the satellite using the doppler shift principle; and Navy TRANET equipment to provide the distance from the satellite to an interrogating station of the Army Secor network; radio range and range-rate transponders for simultaneous determination of satellite-to-ground-station range and line-of-sight velocity, using the NASA STADAN system; two C-band transponders and passive reflector, for range radar calibration and experimentation to determine the accuracy of the system for satellite geodesy application; and laser detector (photomultiplier) and corner reflectors, consisting of 400 quartz prisms with a total reflecting area of 360 square inches – about 50 percent more reflecting area than GEOS I. Satellite systems included a motor-operated 60-foot gravity gradient boom for stabilization, vector magnetometers for measuring orientation, dual command receiver, clock and memory system to support experiments, and telemetry. Three independent power systems; main power system consisted of 2304 n/p solar cells and one nickel-cadmium battery providing 16 to 20 watts; optical power system and transponder power system each contained 1344 n/p solar cells

and a nickel-cadmium battery providing 9 to 12 watts. Thermal design included multilayer insulation, two 1-inch aluminum tube heat pipes containing freon 11 to minimize temperature differences among the three transponder packages.

Project Results – Explorer XXXVI was launched on January 11, 1968 from Vandenberg AFB into a near-nominal 671/976-mile orbit at 105.8° inclination. Optimum stabilization was achieved by extending the gravity gradient boom to 30 feet.

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management, experimenter; Applied Physics Laboratory, Johns Hopkins Univ., spacecraft prime contractor; Ohio State Univ., UCLA, Smithsonian Astrophysical Observatory, AF Cambridge Research Laboratories, USN Pacific Missile Range, experimenters; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PS	H.R. Stanley	NASA-WFC
MG	C.J. Finley	NASA Headquarters
SC	J.P. Murphy	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Optical Beacon System	PI	R.F. Williston	Applied Physics Laboratories
Laser Corner Reflector	PI	H.H. Plotkin	NASA-GSFC
	OI	C.C. Stephanides	NASA-GSFC
Navy Doppler System	PI	R.J. Anderle	US Naval Surface Weapons Center
US Army Secor System	PI	J.S. McCall	USA Office Chief Engineering
Goddard Radar System	PI	J.H. Berbert	NASA-GSFC
C-Band Radar System	PI	J. Stanley	NASA-WFC
NASA Minitrack Network	PI	J.M. Kohout	NASA-GSFC
Precipitating Electrons	PI	C.O. Bostrom	Applied Physics Laboratories
Magnetometer	PI	Unknown	Unknown

APOLLO V

Launch Vehicle – Uprated Saturn I (AS-204): S-IB first stage containing eight H-1 engines producing a total first stage thrust of 1.6 million pounds; S-IVB second stage containing a single J-2 engine at 200,000 pounds of thrust. Instrument Unit (IU), a cylinder 3 feet high and 21 feet 8 inches in diameter mounted atop second stage, contained electrical and mechanical equipment for guiding, controlling, and monitoring vehicle performance from liftoff until after insertion of spacecraft into orbit. Telemetry hardware contained in IU, as well as that contained in S-IB and S-IVB stages, had all been flown successfully in three previous Apollo missions. Height: 181 feet including nose cone.

Spacecraft Description – Lunar Module I (LM I), consisting of ascent stage and descent stage. Ascent stage comprised five structural areas: crew compartment, midsection, aft equipment bay, tank and equipment mountings, and outer skin and insulation. Crew compartment was a pressure-tight unit some 92 inches in diameter; together with midsection it constituted the entire pressurized volume available for crew operation in the LM. Aft equipment bay was an aluminum alloy frame secured to the aft midsection by aluminum alloy trusswork. Complete ascent stage covered with a thermal and meteoroid shield of thin aluminum and aluminized Mylar. Ascent engine extended from bottom of midsection to top of descent stage. Weight of ascent stage without propellants: 4850 pounds. Descent stage, octagonal in shape, constructed of aluminum alloy in conventional skin and stringer arrangement; housed the descent engine together with associated fuel and tankage and – on lunar missions – scientific equipment to be used on lunar surface. Main load-carrying structure of descent stage consisted of two pairs of parallel beams in cruciform arrangement, together with upper and lower decks and enclosure bulkheads. Additional support and strut assemblies secured to the main beams to form diagonal bays or quadrants. Outriggers extending from the ends of each pair of beams provided four points of attachment to the spacecraft LM adapter. Landing gear was not carried on LM I. Weight of descent stage without propellants: 3650 pounds. Weight of LM I including propellants: 31,700 pounds. Spacecraft LM Adapter (SLA): a truncated cone 28 feet high, 12.8 feet in diameter at the top, and 21 feet in diameter at the bottom, the SLA housed the LM and connected the nose cone to the launch vehicle instrumentation unit. Constructed of 1.7-inch aluminum honeycomb bonded to aluminum face sheets of varying thickness, the SLA divided into four movable panels. Before deployment of the LM, the panels were sheared from one another along seam lines by means of pyrotechnic devices. Weight: 3950 pounds. Spacecraft LM Adapter (SLA) nose cone, 11.3 feet tall and tapered 25 degrees to a base 12.8 feet in diameter, provided aerodynamic continuity to the launch vehicle-SLA structure. The union between the nose cone and the SLA was sheared by a mild detonating fuse. Weight of SLA: 1067 pounds.

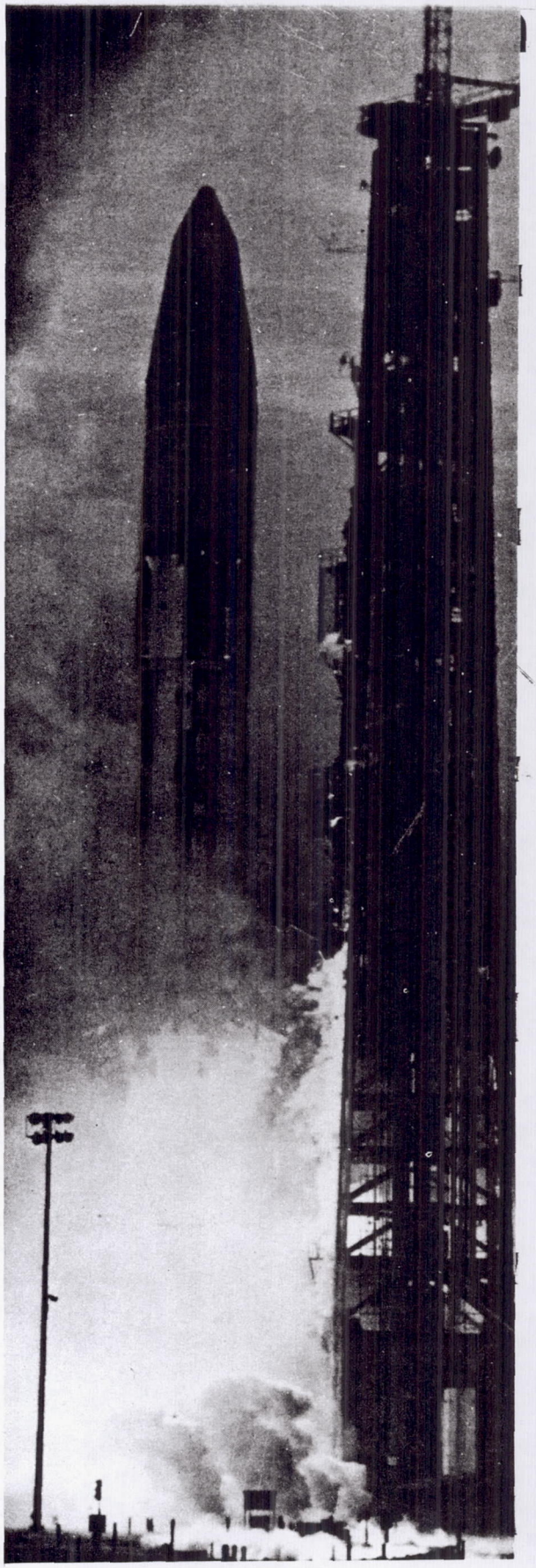
Project Objectives – Verify operation of the descent and ascent propulsion systems, including restart; demonstrate spaceworthiness of LM structure; evaluate LM staging; and evaluate launch vehicle performance.

Spacecraft Payload – Major LM I subsystems included electrical power system (EPS), environment control system (ECS), communication system (COMM), primary guidance and navigation system (PGNS), reaction control system (RCS), descent engine, ascent engine, and LM mission programmer (LMP). In the EPS, DC power provided by six silver-zinc primary batteries, four electrical control assemblies, and two DC buses. AC power provided by two single-phase AC inverters and one AC bus, located in the ascent stage. Only one inverter powered the bus at any given time. The ECS controls atmospheric temperature and pressure in LM cabin and crew suits, supplies water and oxygen for the portable life support system. Major portion of the ECS is in the ascent stage pressurized equipment compartment, which contains two gaseous oxygen tanks (filled to 4.35 psia for LM I) and a portion of the glycol loop. The ascent stage also contained two ECS water tanks. Contained in the descent stage are a larger water tank (installed but not loaded on LM I), an oxygen tank and pressure regulator (not installed on LM I), and a portion of the glycol loop. COMM system consisted of two S-band transceivers and power amplifiers, two VHF/AM transceivers, two audio centers, a premodulation processor, and associated antennas. (The operational VHF/AM transceivers were not installed on LM I; the audio centers were installed but not used.) LM I PGNS consisted of an inertial subsystem and a computer subsystem. Two operational PGNS subsystems were deleted from LM I: the alignment optical telescope and the rendezvous radar. Likewise, the LM abort guidance section was not carried on LM I. RCS engine clusters consisted of four rocket engine assemblies, each engine delivering about 100 pounds of thrust from parallel, independent, helium-pressurized propellant delivery systems. Able to operate in either a pulsed or steady-state mode, the RCS supplied thrust for spacecraft stabilization during ascent and descent burns, for controlling vehicle attitude during maneuvers, for separation maneuvers, and for ullage maneuvers to settle propellants in ascent and descent stage tanks. The LM descent engine had 10,500 pounds maximum rated thrust. It was throttleable from 9710 to 1050 pounds of thrust and could be gimballed ±6° in any direction. The ascent engine, with 3500 pounds of thrust, was neither throttleable nor gimballed. Propellants were the same as those for the LM RCS and descent engine: hypergolic, with nitrogen tetroxide for oxidizer and a 50/50 blend of hydrazine and unsymmetrical dimethyl hydrazine for fuel. LM mission programmer, which replaced the human pilot in LM I, consisted of four basic units: program command assembly, containing taped contingency programs for use in the event of guidance computer failure; digital command assembly, providing uplink capability for routing ground signals; program coupler assembly, providing coupling of the guidance computer commands and program reader commands; and the power distribution assembly, providing 28-volt DC power distribution and current protection.

Project Results – Apollo V was launched from Cape Kennedy on January 22, 1968 and inserted by the S-IVB second stage into an initial orbit of 101/138 miles at 31.6° inclination. Saturn IB performance was close to nominal. Following jettison of the nose cone and deployment of the SLA panels, LM I was successfully separated from the S-IVB second stage. First of the two planned descent engine burns was commanded at T±3 hours, 59

minutes, and 40 seconds. However, the guidance computer initiated shutdown 4.3 seconds later (instead of the planned 6 minutes, 42 seconds) when, because of overly-conservative programming, it determined that the required velocity change had not been achieved in the time allowed. Premature cutoff resulted in shifting to an alternate mission sequence, which differed from the planned sequence principally in the deletion of a 12-minute descent engine burn and substitution of two shorter burns, and substitution of program reader assembly control in place of primary guidance control during burns. Second and third descent engine burns were normal. The second burn lasted 26 seconds at 10 percent thrust followed by 7 seconds at maximum thrust. The third burn was 26 seconds at 10 percent thrust followed by 2 seconds at maximum thrust. Both ascent engine burns were normal. First ascent engine burn, lasting 60 seconds, was initiated during the third descent engine shutdown to simulate abort staging (fire-in-the-hole), and separated ascent stage achieved a 107/598-mile orbit at 31.5° inclination. Second ascent engine burn, during which spacecraft was rate stabilized in a retro attitude, was allowed to continue until fuel depletion – approximately 6 minutes. The best information available indicated that ascent stage decayed west of Hawaii during the sixth revolution. Descent stage decayed 2-12-68. Vehicle structural integrity was maintained throughout the mission. There were no indications of any thermal control problems, and the environmental control system, communication system, and instrumentation system all performed normally.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; Grumman, Lunar Module prime contractor; TRW, descent engine; Bell Aerosystems, ascent engine; United Aircraft, environmental control system; RCA, communications, rendezvous radar; Eagle Picher, electrical power system; General Motors, guidance and navigation; Marquardt, reaction control system; Bulova Watch, LM mission programmer; American Bosch Arma, signal conditioner electronic assembly; Aerojet-General, General Motors, ascent stage propellant tanks; Garrett AiResearch, supercritical helium tanks; NASA Marshall Space Flight Center, launch vehicle management; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, tracking and data acquisition; Chrysler, first stage prime contractor; McDonnell Douglas, second stage prime contractor; IBM, Instrument Unit.



Launch of Apollo V and first flight test of the lunar module. The mission verified the ascent and descent stages of the propulsion systems.

OGO V

Launch Vehicle – Atlas SLV-3A Agena D: 390,000-pound-thrust Atlas first stage, 16,000-pound-thrust Agena D second stage. First stage radio guided, second stage inertially guided. Height: 120.5 feet including shroud.

Spacecraft Description – Essentially identical to OGO IV: rectangular main body 6 feet long, 3 feet wide, 3 feet deep. Appendages included a 22-foot boom extending from each end, four 6-foot booms, two solar panels 7½ feet long and 6 feet wide, and orbital plane experiment packages 18 inches long, 10 inches wide, and 10 inches deep. Heaviest OGO yet, weighing 1347 pounds.

Project Objectives – Conduct a series of comprehensive measurements over a wide range of energy characteristics in the earth's trapped radiation belts, through the magnetosphere, and in interplanetary space. Demonstrate operation of OGO's three-axis stabilization system in a highly elliptical orbit for a period of 135 days or more.

Spacecraft Payload – Record 25 experiments studied similar parameters to those on earlier OGO's. Two new experiments were an electric field experiment which studied DC electric fields in the solar wind, the transition region, and the outer regions of the magnetosphere; and a spark chamber experiment intended to determine the origin of cosmic rays by detecting and studying gamma rays. Another experiment used a Langmuir probe to measure electron density and temperature in order to determine how electrons carried by solar wind gets into the ionosphere. Since most of the electrons are deflected by the magnetosphere, some scientists believe they enter through the polar regions. Two solar arrays and two 28-volt DC nickel cadmium batteries provided maximum power output of about 550 watts. Three-axis stabilization provided by a combination of horizon scanners, sun sensors, gas jet system, and electrically-driven flywheels (utilized to store and dump momentum), and associated electronics. Combined active and passive thermal control system utilizes heaters, radiating panels, and aluminum louvers. Communications and data handling system transmits in real time or stores up to 24 hours of data.

Project Results – OGO V was launched on March 4, 1968 from Cape Kennedy into a near-nominal orbit of 180/91,260 miles at 31° inclination. Initial results included the first evidence of electric fields in the bow shock (shock wave observed in solar wind as it encounters earth's magnetosphere). Other results indicated electric field discontinuities in the solar wind and new particle and field phenomena. The low-energy electrons and protons experiment failed (cause not determined) on March 11 after about 100 hours. Three others have suffered partial degradation, and the digital output of a fifth has failed, but the remainder remained operational.

Major Participants – NASA Goddard Space Flight Center, spacecraft man-

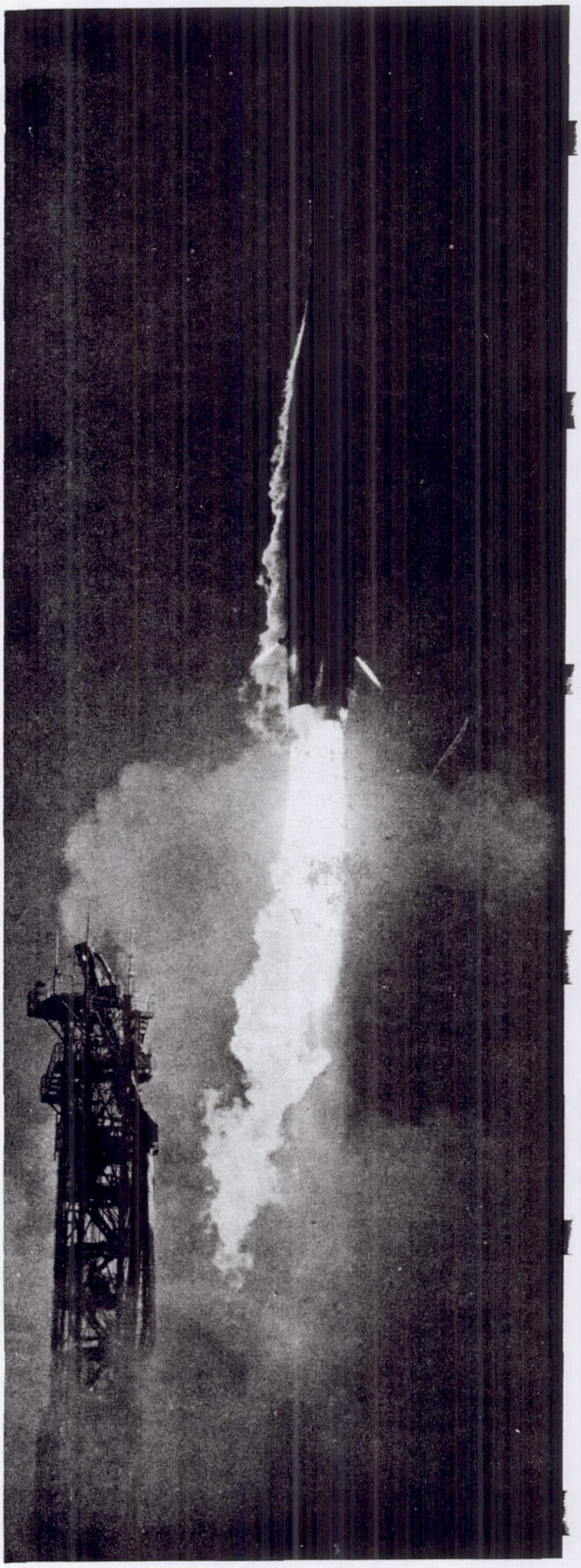
agement, experimenter; TRW spacecraft prime contractor, experimenter; Air Force Cambridge Research Laboratory, Lawrence Radiation Laboratory, U.S. Naval Research Laboratory, JPL, Cosmic Ray Working Group (Netherlands), University College (London), and Univs. of California, Chicago, Colorado, Iowa, Michigan, and Paris, experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics, first stage prime contractor; Lockheed, second stage prime contractor, experimenter.

Key Spacecraft Personnel		Affiliation
PM	W.E. Scull	NASA-GSFC
PS	J.P. Heppner	NASA-GSFC
CO	J.J. Quann	NASA-GSFC
CO	D. Stewart	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Spherical Electron Temperature + Density + Flux	PI	R.L.F. Boyd	University College London
	OI	A.P. Willmore	University of Birmingham
	OI	K. Norman	University College London
Spherical Plasma Temperature + Density + Flux	PI	R.C. Sagalyn	USAF Geophysics Laboratory
	OI	M. Smiddy	USAF Geophysics Laboratory
Retarding Poten Analyzer, E + P	PI	G.P. Serbu	NASA-GSFC
	OI	E.J. Maier	NASA-GSFC
X-Ray + Particle Det, Solar Flare	PI	K.A. Anderson	University of California, Berkeley
	OI	S.R. Kane	University of California, Berkeley
	OI	H. Mark	NASA-ARC
Scintillator Telemetry, EL + Posit + P + Gam	PI	T.L. Cline	NASA-GSFC
Electron Spect + Proton Telemetry	PI	H.I. West, Jr.	Lawrence Livermore Laboratory
	OI	R.G. D'Arcy, Jr.	Unknown
	OI	L. Mann	Lawrence Livermore Laboratory
Cyl. Anal, EL + Prot./ GM Tube	PI	L.A. Frank	University of Iowa
	OI	J.A. Van Allen	University of Iowa
	OI	T.A. Fritz	NOAA-ERL
	OI	T.P. Armstrong	University of Kansas
	OI	S.M. Krimigis	Applied Physics Laboratories

Experiment	Experiment Personnel		Affiliation
Spark Chamber, Gamma + PRI CR	PI	G.W. Hutchinson	University of Southampton
	OI	D. Ramsden	University of Southampton
	OI	R.D. Wills	ESA-ESTEC
Particle Telemetry, CR Electrons	PI	P. Meyer	University of Chicago
	OI	C.Y. Fan	University of Arizona
	OI	J.J. L'Heureux	University of Arizona
Count.Tele., Gal + Solar CR	PI	F.B. McDonald	NASA-GSFC
	OI	G.H. Ludwig	NOAA-NESS
	OI	V.K. Balasubrahmanyan	NASA-GSFC
	OI	D.E. Hagge	Unknown
Tri-Axis 10 to 10keV Electron	PI	K.W. Ogilvie	NASA-GSFC
	OI	T.D. Wilkerson	University of Maryland
CNTR. TELE., CR Electrons	PI	H.C. Van De Hulst	Huygens Laboratory
	OI	D. Tanka	Netherlands Institute
	OI	M.N. Lind	Netherlands Institute
Electron Pitch Angle Distribution	PI	P.J. Coleman, Jr.	University of California, Los Angeles
	OI	T.A. Farley	University of California, Los Angeles
	OI	D.L. Judge	University of Southern California
Tri-Axis Fluxgate Magnetometer	PI	P.J. Coleman, Jr.	University of California, Los Angeles
	OI	T.A. Farley	University of California, Los Angeles
	OI	D.L. Judge	University of Southern California
	OI	C.T. Russell	University of California, Los Angeles
Tri-Axis Fluxgate + Rubidium V. Magnetometer	PI	J.P. Heppner	NASA-GSFC
	OI	B.G. Ledley	NASA-GSFC
	OI	M. Sugiura	NASA-GSFC
	OI	T.L. Skillman	NASA-GSFC
	OI	R.M. Campbell	Unknown
Tri-Axis Search Coil Magnetometer	PI	E.J. Smith	NASA-JPL
	OI	R.E. Holzer	University of California, Los Angeles
3keV to 16keV Plasma Analyzer	PI	C.W. Snyder	NASA-JPL
	OI	M.M. Neugebauer	NASA-JPL
	OI	J.L. Lawrence, Jr.	NASA-JPL
Magnetometer Ion Mass Spectrometer	PI	G.W. Sharp	NASA Headquarters
	OI	T.J. Crowther	Unknown
	OI	K.K. Harris	Lockheed Palo Alto
Radio Astronomy, 50KHz-3.5MHz	PI	F.T. Haddock	University of Michigan

Experiment	Experiment Personnel		Affiliation
UV Airglow, 1304A and 1216A	OI	G.E. Thomas	University of Colorado
	PI	C.A. Barth	University of Colorado
	OI	J.B. Pearce	Science Applications, Incorporated
	OI	E.F. Mackey	Packard-Bell Corporation
Geocoronal Lyman Alpha	PI	J.E. Blamont	CNRS-SA
Solar X-Ray, 2 to 20keV, Pro. CT	PI	R.W. Kreplin	US Naval Research Laboratory
	OI	T.A. Chubb	US Naval Research Laboratory
	OI	H.D. Friedman	US Naval Research Laboratory
	OI	C.S. Bowyer	University of California, Berkeley
Plasma Waves, Elec + Mag Ant	PI	G.M. Crook	Gaines M. Crook Associates
	OI	F.L. Scarf	TRW Systems Group
	OI	R.W. Fredericks	TRW Systems Group
	OI	I.M. Green	TRW Systems Group
OPEP-2 Scan Mechanism	PI	R.K. Browning	NASA-GSFC
Electric Field Antennas	PI	T.L. Aggson	NASA-GSFC
	OI	N.C. Maynard	NASA-GSFC
	OI	J.P. Heppner	NASA-GSFC
High-Z,Low-E Part., SS Tele.	PI	J.A. Simpson	University of Chicago
	CO	G. Lentz	University of Chicago



OGO-V, the fifth orbiting geophysical observatory lifts off from Cape Kennedy. Other countries providing experiments included England, France, and the Netherlands.

EXPLORER XXXVII
(Solar Explorer B)

Launch Vehicle – Solid-propellant Scout: 100,944-pound-thrust Algol IIB first stage, 60,764-pound-thrust Castor I second stage, 20,942-pound-thrust Antares (X-259) third stage, and 5746-pound-thrust FW-4S fourth stage. First three stages inertially guided, fourth stage spin-stabilized. Height: 72 feet.

Spacecraft Description – A 12-sided cylinder, 30 inches in diameter and approximately 27 inches high. Mounted on a central band around the middle were X-ray photometers, Geiger tubes, photomultipliers, solar aspect system, and attitude control and spin nozzles. Solar cells, contained in 24 7-inch x 10-inch panel arrays, covered the remainder of the vertical sides. Four radio antennas extended from the top, four from the bottom. Weight: 198 pounds.

Project Objectives – Measure and monitor selected solar X-ray and ultraviolet emissions. Data for distribution to a number of users, including ESSA's Space Disturbances Forecasting Center at Boulder, Colorado.

Spacecraft Payload – A scintillation counter, two Geiger tubes, and five X-ray photometers measure X-rays in the 0.1-0.5, 0.5-3, 1-8, 1-20, 8-16, and 44-60Å bands. Two ultraviolet photometers measure ultraviolet radiation in the 1080-1350 and 1225-1350Å bands. Communications equipment included two analog transmitters for continuous operation, a digital transmitter to operate on command only, two four-element antenna systems, and two command receivers connected to a decoder system for placing spacecraft and experiments in desired operating modes. Two telemetry systems, one consisting of six subcarrier oscillators, the other of four, provided outputs which were utilized to transmit both housekeeping and experiment data. A magnetic core memory system collected data from three X-ray detectors over a 14-hour period, transmitted the digitized data to the ground station on command, then was reset to collect data for another 14-hour period. Low-thrust vapor jets maintained spin rate (about 1 rpm) and control of spin axis; two sun sensors located 180° apart generated properly-timed jet pulses to precess the spin axis. Silicon solar cells and nickel-cadmium batteries supplied 27 watts of power.

Project Results – Explorer XXXVII was launched on March 5, 1968 from Wallops Island. Due to first stage malfunction, the spacecraft failed to reach its intended 520-mile circular orbit, and instead went into a 545/324-mile orbit at 59.4° inclination. However, the off-nominal orbit did not prevent attaining the scientific objectives, and the mission was adjudged a success.

Major Participants – U.S. Naval Research Laboratory, spacecraft prime contractor, experimenter; NASA Goddard Space Flight Center, tracking services, NASA Langley Research Center, launch vehicle management; LTV, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	R.W. Kreplin	US Naval Research Laboratory
MG	J.R. Holtz	NASA Headquarters
SC	G.K. Oertel	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Solar Radiation	PI	R.W. Kreplin	US Naval Research Laboratory
	OI	T.A. Chubb	US Naval Research Laboratory
	OI	H.D. Friedman	US Naval Research Laboratory

APOLLO VI

Launch Vehicle – Saturn V (SA-502), essentially identical to that used for Apollo IV except for addition of launch vehicle instrumentation: S-IC first stage with over 7,500,000 pounds of thrust; S-II second stage at 1,000,000 pounds of thrust; S-IVB third stage at 200,000 pounds of thrust. All three stages inertially guided. Saturn V Instrument Unit, a cylinder 3 feet high and 21 feet 8 inches in diameter mounted atop third stage, contained vehicle electronics for navigation, guidance and control, measurement of vehicle performance and environment, telemetry, command reception, checkout and monitoring of vehicle functions, power generation and distribution, and preflight checkout and launch. Height: 363 feet.

Spacecraft Description – Block I (earth-orbit type) Command Module, Service Module, Spacecraft Lunar Module Adapter, and Lunar Module Test Article LTA-2R. Except for new crew hatch on Command Module, Apollo VI spacecraft was basically the same as that for Apollo IV Command Module, a cone 12 feet high with base diameter of 12 feet 10 inches, had a heatshield outer structure of stainless steel honeycomb bonded between steel alloy sheets, with surface application of phenolic epoxy resin ablative material. Inner structure fabricated from aluminum honeycomb between aluminum alloy. Outer and inner structures separated by fibrous insulation and support stringers. A total of 12 attitude control jets located on exterior of Command Module. The new quick-operating, outward-opening unified crew hatch was flown for the first time as a complete unit on Apollo VI (flexible thermal seals for the new hatches were successfully tested on Apollo IV). Constructed of aluminum with a fiberglass and ablative material covering and containing a window, the hatch was 27.03 inches high and tapered in width from 26.85 inches at the bottom to 25.73 inches at the top. Included a vent valve which permitted quick depressurization of cabin from inside or outside. Could be unlatched in about 5 seconds or sealed from within by operating a permanently-mounted lever inside, and opened or sealed from outside with the aid of a hand tool. A device powered by pressurized nitrogen counters the force of gravity and seal friction to provide positive hatch opening. Weight of Command Module: about 12,500 pounds. Service Module, a cylinder 12 feet 10 inches in diameter and 22 feet in length, joined to and supported the Command Module at the top and extended to the service propulsion system (SPS) engine at the bottom. Outer structure consisted of aluminum honeycomb 1 inch thick, forming six panels bolted to solid aluminum structural uprights. Interior, divided into wedge-shaped compartments around center cylindrical section, contained auxiliary equipment, SPS fuel, oxidizer, and helium pressurization tanks. Space radiators to dissipate heat from electrical power system and environmental control system were located externally on four of the six Service Module panels (but – as on Apollo IV – were left unconnected). Four attitude control system packages, each containing four engines and fuel tank, oxidizer tank, and pressurant tank, were spaced equidistant around circumference of Service Module. Weight of Service Module: 42,600 pounds. Spacecraft Lunar Module Adapter, which housed the Lunar Module Test Article, was a tapered cylindrical shape 28 feet high, its 22-foot-diameter base joining to the S-IVB third stage and 12-foot 10-inch top joining to and supporting the Service Module. Weight of

adapter: 3800 pounds. Lunar Module Test Article LTA-2R included a flight-type descent stage without landing gear, and with propellant tanks filled with water glycol and freon to simulate fuel and oxidizer. Ascent stage was a ballasted aluminum structure containing no flight systems. Like the Lunar Module Test Article flown on Apollo VI, LTA-2R remained attached to S-IVB third stage; was instrumented to measure vibration, acoustics, and structural integrity at 36 points. Weight of LTA-2R: 26,000 pounds.

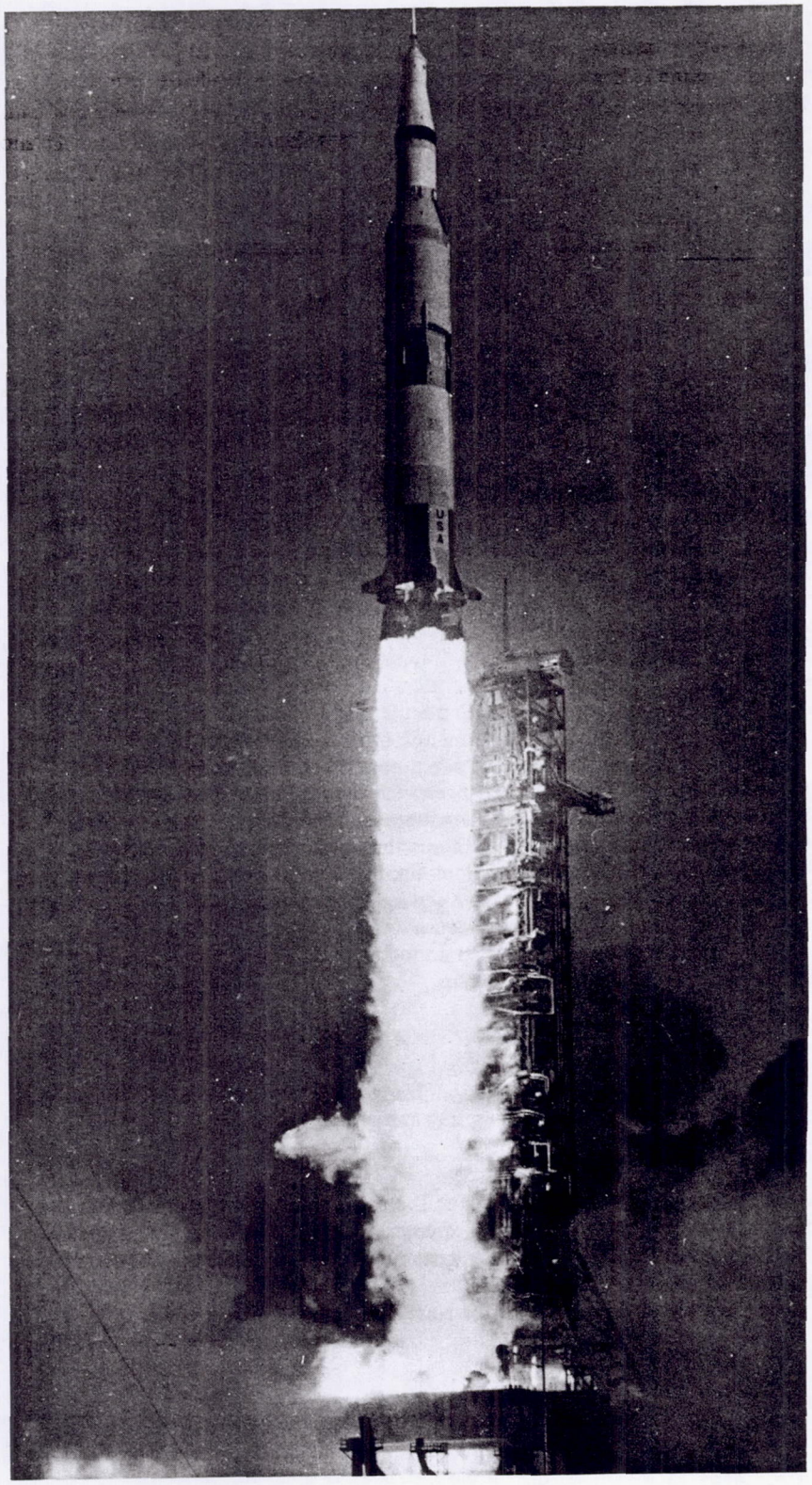
Project Objectives – Primary objectives were to demonstrate the structural, thermal propulsion, and separation characteristics of all three stages of the Saturn V in powered flight, and to qualify the third-stage continuous vent system, its auxiliary propulsion system, and the J-2 engine restart capability while in orbit.

Spacecraft Payload – Launch vehicle instrumentation included 23 telemetry systems, four tracking systems, one command system, six motion picture cameras in recoverable capsules, and two television cameras, providing a total of 2800 measurements. Command Module included a movie camera for filming boost protective cover jettison and orbital insertion, re-entry horizon reference, window degradation, and re-entry plasma flow and brilliance, and a still camera for earth photos. Also flown on Command Module were three ablator test panels for use in determining possible weight-saving techniques and in evaluating materials for future ablative applications. Other spacecraft systems were practically identical to those in Apollo IV. Command Module contained an Apollo mission programmer to operate spacecraft subsystems in the absence of a crew. Thrust for major velocity changes – and (in earth orbit missions) for de-orbit burn to achieve re-entry – provided by 21,000-pound-thrust hypergolic-fueled SPS engine. Stabilization and control provided by three body-mounted attitude gyros, rate gyro assembly, pendulous accelerometer, attitude set and gimbal position indicators, velocity change indicator, and associated electronic control and signal conditioning equipment. Semi-automatic guidance computer, and display and keyboard panels. Electrical power provided by hydrogen-oxygen fuel cells and zinc-silver oxide batteries together with associated DC converters and power distribution equipment. Environmental control system consisted of water and glycol circulating systems. Telecommunications provided by data processing equipment including signal-conditioning, data storage, central timing, up data digital decoding, pulse-code modulation, and premodulation processing equipment; RF electronics equipment including VHF/FM transmitter and VHF/AM transceiver, C-band transponder, unified S-band equipment, VHF recovery beacon, and HF transceiver; and associated VHF omnidirectional, S-band, VHF recovery, HF recovery, and C-band antennas. Parachute subsystem included two 13.7-foot-diameter conical nylon drogue chutes, three 7.2-foot-diameter nylon pilot chutes, and three 83.5-foot-diameter nylon main chutes. Spacecraft recovery from water facilitated by compressor-inflated bags to achieve upright position, fluorescent sea dye marker, flashing beacon on Command Module apex, VHF transmitter, and swimmer's umbilical. Launch Escape System, a structure 33 feet tall with a 4-foot base

diameter, was designed to pull the Command Module up and away from the launch vehicle in the event of mission abort, either on the pad on during launch to an altitude above 270,000 feet. Included a boost protective cover at base of tower which fit over the apex of the Command Module for protection against boost heating as well as against the exhaust of the launch escape motors. Launch Escape System jettisoned shortly after second stage ignition. Earth landing under abort conditions employed parachute system essentially the same as in normal re-entry descent.

Project Results – Apollo VI was launched from Cape Kennedy on April 4, 1968. Following a malfunction of the Number 2 engine on the S-II second stage, an engine cutoff command was initiated but, because of incorrectly installed command wires, was routed to the Number 3 engine instead. To compensate for the degraded performance, the three remaining engines were fired until fuel depletion – approximately 58 seconds longer than planned – and the initial S-IVB third stage burn was extended approximately 29 seconds longer than planned. Initial parking orbit was 111/226 miles (instead of the planned 116/122 miles) at 32.5° inclination. When the S-IVB third stage, intended to boost the spacecraft into a simulated lunar trajectory, failed to restart, spacecraft separation was commanded and the SPS engine was ignited. The ensuing 7-minute 25-second SPS burn – its longest single inflight burn to date – achieved the desired apogee, but left insufficient propellants for the planned second burn, which would have increased re-entry velocity to about 36,500 fps. Other anomalies included excessive longitudinal vibrations ("pogo" effect) induced by synchronized, pulsating thrusting of the five first stage engines; this in turn apparently caused separation of material from the spacecraft Lunar Module Adapter during first stage thrusting. Spacecraft reached an apogee of 13,840 miles, and 6-hour cold soak was accomplished as planned. Re-entry velocity reached 32,776 fps; recovery point was at approximately 27°38′N, 157°0′W. Except for minor problems, all spacecraft systems, including the new crew hatch, performed normally throughout the mission.

Mission Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell, spacecraft prime contractor, Command and Service Modules, second stage prime contractor; Grumman, Lunar Module Test Article; NASA Marshall Space Flight Center, launch vehicle management; Boeing, first stage prime contractor; McDonnell Douglas, third stage prime contractor; IBM, Instrument Unit; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, tracking and data acquisition.



Apollo VI liftoff at Merritt Island, Fla.

1968

INTERNATIONAL RADIATION SATELLITE-I ESRO IIB

Launch Vehicle – Solid-propellant Scout: 101,000-pound-thrust Algol IIB first stage, 61,000-pound-thrust Castor II second stage, 21,000-pound-thrust Antares II third stage, and 5750-pound-thrust FW-4S fourth stage. First three stages inertially guided, fourth stage spin stabilized. Height: 72 feet.

Spacecraft Description – 12-sided cylinder 30 inches in diameter and 33.5 inches high. Sides covered by solar cells except for narrow experiment band around midsection. Experiment instrumentation located at top, bottom, and around mid-band. Four telemetry and command antennas, each about 20.3 inches long, extended from bottom. Weight: 164 pounds.

Project Objectives – ESRO IIB carried seven experiments to study solar and cosmic radiation in lower layer of Van Allen belt over a period of 6 months.

Spacecraft Payload – Seven experiments, duplicating those on ESRO IIA and similar to those carried on NASA's OSO (Orbiting Solar Observatory) series, including energetic particle flux counters, solar and Van Allen belt proton detectors, solar and galactic alpha particle and proton telescope, primary cosmic ray electron counter, hard solar X-ray spectrometer, soft solar X-ray detectors, and solar and galactic cosmic ray particle flux and energy spectrum detectors. Telemetry system included both real-time and recorded data links; tape recorder, with 110-minute maximum storage capacity, capable of playing back stored data from one orbit in approximately 3.5 minutes via 1.6-watt transmitter. Of the seven experiments on board, four were directly concerned with the sun, three with the interplanetary region. Power system included 3456 n/p solar cells supplemented during shadow periods by a nickel-cadmium battery; voltage maintained between 16.8 volts minimum and 23.4 volts maximum. Spin-stabilized at 30-40 rpm by cold gas spinup system, after being despun from separation spin of 160-180 rpm by a yo-yo system consisting of two equal weights attached to the satellite by tapes. Ball-in-tube nutation damper used to reduce or eliminate spacecraft coning angle. Passive thermal control.

Project Results – Launched on May 17, 1968 from Vandenberg AFB into a polar, sun-synchronous orbit (205/677 miles at 97.2° inclination). Six of the seven experiments were operating as planned.

Major Participants – European Space Technology Center, spacecraft management; Hawker Siddeley Dynamics, spacecraft prime contractor; Engins Matra, attitude control and power supply systems; TRW, spacecraft general consultant; Imperial and University Colleges (London), Univs. of Leeds, Leicester, and Utrecht, and Saclay Center for Nuclear Physics, experimenters.

Key Spacecraft Personnel		Affiliation
PM	A. Kutzer	Ges Fur Weltraumforschung
PS	D.E. Page	ESA-ESTEC
PM	H.L. Eaker	Unknown
PS	L.H. Meredith	NASA-GSFC
CO	J.P. Talentino	NASA-GSFC
CO	J.L. Michael	NASA-GSFC
CO	L.H. Anderson	NASA-GSFC
CO	R.D. Werking	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Energetic Particle Flux	PI	H. Elliot	Imperial College
	OI	J.J. Quenby	Imperial College
	CO	A. Bewick	Imperial College
Solar + VA Belt Protons	PI	H. Elliot	Imperial College
	OI	J.J. Quenby	Imperial College
	OI	R.J. Hynds	Imperial College
Solar/Galactic Alpha + Proton	PI	H. Elliot	Imperial College
	OI	J.J. Quenby	Imperial College
	OI	A.C. Durney	ESA-ESTEC
Primary Cosmic Ray Electrons	PI	P.L. Marsden	University of Leeds
	OI	J.G. Wilson	University of Leeds
	OI	R. Jakeway	University of Leeds
Hard Solar X-Rays	PI	E.A. Stewardson	Unknown
	OI	R.L.F. Boyd	University College London
	OI	J.L. Culhane	University College London
	OI	P.J. Bowen	University College London
	OI	K.A. Pounds	University of Leicester
Soft Solar X-Rays	OI	W. Degraaf	Astronomical Institute
	OI	A.C. Brinkman	University of Utrecht
	PI	C. De Jager	University of Utrecht
Flux/En. Spec. Sol/ Gal. CR.	PI	J. Labeyrie	CENS
	OI	L. Koch	CENS
	OI	J. Engelmann	CENS

NIMBUS B (SECOR 10)

Launch Vehicle – NASA's first use of Air Force Thorad (Long-Tank Thor)-Agena D: 170,000-pound-thrust Thor first stage, augmented by three 51,490-pound-thrust strap-on solid-propellant motors and two liquid bi-propellant vernier engines at 1060 pounds thrust each. Agena D second stage at 16,000 pounds thrust. First stage inertially guided with optional radio guidance; second stage inertially guided. Height: 109.5 feet including 18.7-foot shroud.

Spacecraft Description – Nimbus B: like Nimbus I and II, composed of three major elements – 5-foot-diameter sensory ring lower section, hexagonal upper section, and two large solar panels, 8 feet tall and 3 feet wide each. Upper and lower sections connected by truss structure. Sensory ring, a hollow circular section, contained all of the weather measuring experiments as well as spacecraft batteries, transmitters, and associated electronic equipment. Attitude control system housed in upper section. Spacecraft 10 feet tall, 11 feet across solar panels. Weight: 1260 pounds excluding 112-pound adapter. Secor 10: rectangular package 9 x 11 x 13 inches, covered by solar cells. Eight antennas extended from sides, one from top. Weight: 45 pounds.

Project Objectives – Nimbus B: meteorological objectives included study of spatial and temporal distribution of atmospheric structure – particularly temperature – and determination of temporal variations in solar radiation (near ultraviolet). Engineering objectives included demonstration of full spacecraft observatory for handling multiple experiments, radioisotope power for space use, data collection and ranging system, air-bearing gyro, and solid-state S-band transmitter. Ultimate objective was to demonstrate experiments and techniques for achieving reliable, long-range weather forecasting. Secor 10: intended to evaluate Multi-Attitude Transponder, as part of overall mission of continuing the Army's position determination program (Secor: sequential collation of range).

Spacecraft Payload – Nimbus B: of the total nine experiments carried, seven were firsts for the Nimbus program. Infrared Interferometer Spectrometer (IRIS) was to be the first meteorological experiment to provide global measurements of the atmosphere's vertical temperature, water vapor content, and ozone distribution. Utilizing a Michelson interferometer with a 100-mile-diameter field of view, and operating in the 6- to 20-micron region, IRIS was to analyze the infrared spectrum radiated from discrete areas of the earth's surface, or cloud tops, along the orbital path. During each 11-second viewing interval, image motion was to compensate for spacecraft travel. Computer was to compare spectra with ideal black body curves conforming to Planck's radiation formula. IRIS was also to measure air pollution dispersion of nitrous oxide, methane, and carbon dioxide. Weight: 35 pounds. Satellite Infrared Spectrometer (SIRS) was to take similar readings to those of IRIS but would not measure water vapor or ozone distribution. Utilizing a Fastee-Ebert grating spectrometer that would measure atmo-

spheric energy in the 15-micron band, SIRS was to measure vertical temperature profile of earth's atmosphere over an area 120 miles square, directly beneath spacecraft. Weight: 91 pounds. The Interrogation, Recording, and Location System (IRLS) was to locate and identify transmissions from remote terrestrial sensors (weather stations, buoys, drifting balloons, earth strain gauges, and other data platforms), receive and record the data, then relay the results to a ground station for dissemination. Though limited initially to deployment of 12 platforms, IRLS was capable of expansion ultimately to large numbers of surface or airborne units deployed anywhere in the world. Weight: 26 pounds. Monitor of Ultraviolet Solar Energy (MUSE) was to measure solar flux in five broad spectral bands to detect variations of intensity. Ultraviolet radiation is related to formation of ionosphere, establishment of ozone layer, and heating of upper regions of stratosphere. Weight: 9 pounds. Image Dissector Camera (IDC) was to take daily television pictures of the entire earth, each 800-line picture covering about 840,000 square miles and having a resolution of about two miles at picture center, with a total scan time of 200 seconds. Pictures were to be relayed to Automatic Picture Transmission (APT) stations for playback to Goddard Space Flight Center. IDC replaced both the advanced vidicon camera system (AVCS) and APT packages carried on earlier missions. Weight: 14 pounds. SNAP-19 experiment consisted of two radioisotope-fueled thermoelectric generators, each weighing about 28 pounds and mounted one atop the other; was to produce about 50 watts of power to supplement power from solar panels. Rate Measuring Package, consisting of a single-degree-of-freedom rate-integrating air-bearing gyro with assorted conditioning, command, control, and telemetry electronics, was intended to assess performance of an air-bearing gyro package under orbital conditions. Provisions were also made to use this package as backup for regular controls subsystem gyro. High Resolution Infrared Radiometer (HRIR) and Medium Resolution Infrared Radiometer (MRIR) were both similar to their counterparts on Nimbus II. Operating at 3.4 to 4.2 microns in the infrared spectrum, HRIR was to utilize a lead selenide photoelectric cell to take earth and cloud cover pictures, with a 5-mile resolution at picture center, over about a 1500-mile-wide strip on the night side of each orbit. Modification was made over Nimbus II version to allow HRIR to provide useful daytime pictures as well. Weight: 18 pounds. Objectives of MRIR were to determine effect on weather of earth's radiation balance and to map atmospheric motion and jet streams. Consisted of a five-channel radiometer designed to measure albedo radiation as well as atmospheric temperature and relative humidity profiles at various levels. Weight: 21 pounds. Clock and command system used to operate sensor systems. Stabilization in three attitudes provided by ACS employing horizon scanners, coarse sun sensors, yaw gyro, reaction wheels, and freon gas jets. S-band transmitter utilized for photo transmission. Power supply included 10,500 n/p solar cells averaging 211 watts output supplemented by the two SNAP-19 generators. Passive thermal control provided by 32 layers of aluminized insulating material; active thermal control provided by bellows-actuated louvers and six thermal strip heaters. Secor 10: 12-pound solid-state transponder employed to re-transmit signals from four ground stations – three at known locations and fourth at position determined from satellite range measurements. Magnetic stabilization utilized to null out spin; telemetry system carried to monitor satellite performance.

Project Results – Nimbus B was launched on May 18, 1968 from Vandenberg AFB. Two minutes after launch, a booster malfunction forced a command destruct by the range safety officer. The booster and spacecraft fell into the Pacific Ocean between Vandenberg AFB and San Miguel Island off the coast of California. According to radar tracking, the closest point to shore where debris fell was 5 miles from Jalama Beach and 1 mile from San Miguel Island. The radioactive fuel for the two SNAP-19 generators (plutonium 238) was contained in two high-strength alloy and graphite capsules, which had been designed and tested to withstand ocean impact and seawater corrosion in case of such an abort. Extensive tests have shown that under these conditions the fuel would present no hazard to people or marine life.

Major Participants – NASA Goddard Space Flight Center, Nimbus B spacecraft management, prime contractor, chief experimenter; General Electric, Nimbus B structure, antennas, attitude control system, spacecraft integration and test; ADCOLE Corp., MUSE; Brown Engineering, S-band transmitter; California Computer Products, command clock; Hughes, Lockheed, California Computer Products, MRIR; Radiation Inc., Raymond Engineering, Hughes, PCM telemetry; ITT, HRIR, IDC; Radiation Inc., IRLS; RCA, high data rate storage system, command receivers, solar power system, direct readout infrared transmitter; Sperry Gyroscope, RMP; Texas Instruments, IRIS; Martin-Marietta, SNAP-19; AEC, SNAP-19, experimenter; ESSA, SIRS; NASA, USAF, National Center for Atmospheric Research, USN, Woods Hole Oceanographic Inst., Bureau of Commercial Fisheries, IRLS remote platforms; U.S. Army Engineers Topographic Laboratory, Secor management; ITT, Secor 10 prime contractor; A.F. Space and Missile Systems Organization, secondary payload management; NASA Lewis Research Center, launch vehicle management; McDonnell Douglas, first stage contractor; Lockheed, second stage contractor.

EXPLORER XXXVIII (Radio Astronomy Explorer A)

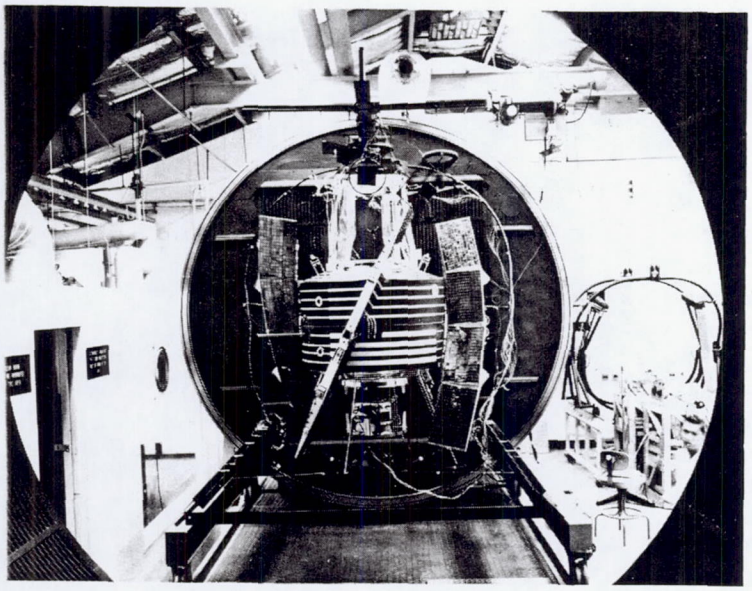
Launch Vehicle – Thrust Augmented Improved Delta (TAID): Thor first stage with three Castor I strap-on solid-propellant motors and total thrust of 333,500 pounds. 7700-pound-thrust second stage, and 6200-pound-thrust FW-4 solid-propellant third stage. First and second stages radio guided, third stage spin stabilized. Height: 92 feet.

Spacecraft Description – Cylindrical aluminum structure with four 5-foot-long helical solar panels deployed around sides, apogee motor nozzle extended from aft end. Sensors and telemetry antenna mounted on outer edges of solar panels. Appendages (extended after reaching final orbit) included two 3/4-pound yo-yo weights attached to 27-foot wires for despinning spacecraft from initial 92 rpm to 2 rpm before being cut loose (final despinning accomplished by three electromagnetic coils); 630-foot-long (maximum) vibration damper extending from forward end (toward earth); 120-foot-long dipole antenna extended in two 60-foot sections from sides along earth horizontal; four 750-foot-long antennas arranged in two 60° angle V's, one V extending toward earth, the other toward space. Each antenna boom stored as 0.002-inch-thick beryllium-copper alloy tape, deployed from motor-driven reels to form ½-inch-diameter tubes. Gravity-gradient stabilized. Weight: 417 pounds.

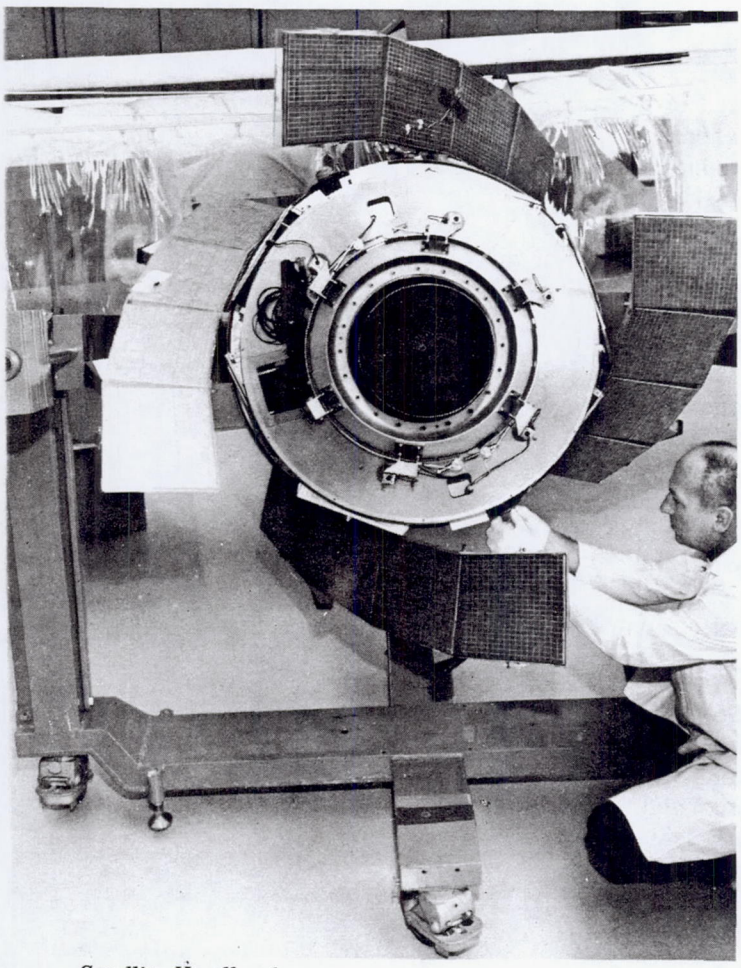
Project Objectives – Monitor low-frequency radio signals from cosmic sources, from our own solar system, and from earth's magnetosphere and radiation belts. Monitor the strong, sporadic radio bursts from region of Jupiter, for correlation with simultaneous high-frequency observations made by global Jupiter Monitoring Network.

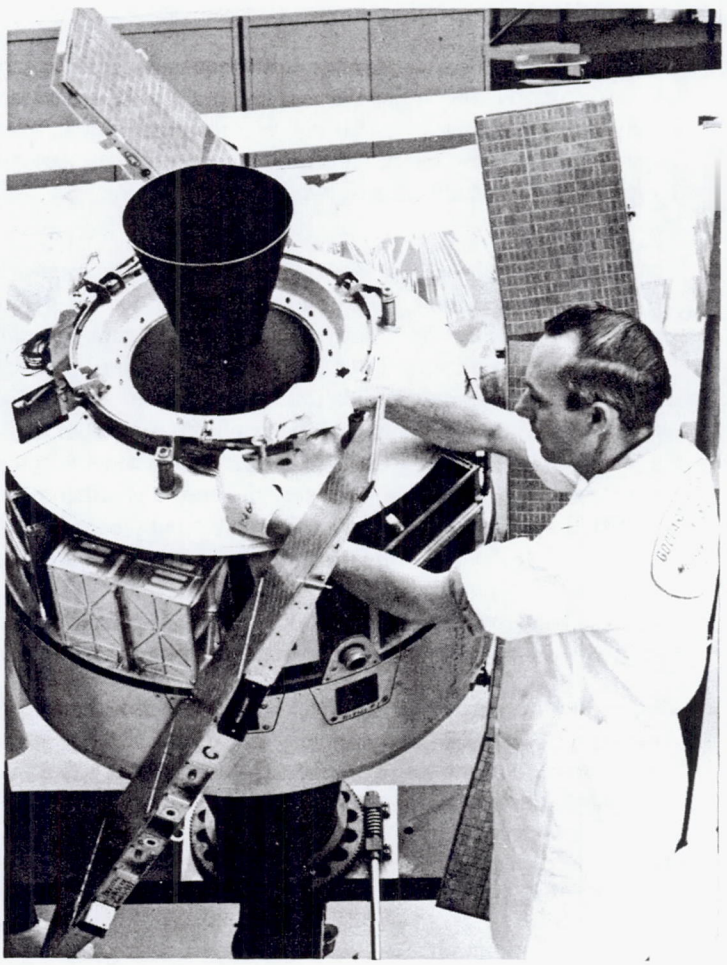
Spacecraft Payload – Upper V antenna array measured intensity of radio signals from solar system and cosmic sources as a function of frequency, direction, and time. Lower V array monitored low-frequency radio emissions from earth's environment. Four slow-scan TV cameras mounted on spacecraft monitored boom deflection during deployment. Instrumentation associated with V antennas included three nine-step radiometers measuring frequencies between 0.45 and 9.2 mHz. Dipole antenna monitors low-frequency radio bursts from Jupiter, the sun, and other possible sources. Associated with dipole was a fourth nine-step radiometer covering same frequency band as the other three, together with two burst receivers – one a 32-step receiver covering the 0.2 – 5.53 mHz range, the other a sweep-frequency unit covering 0.245-3.93 mHz. Also included was an electron trap for measuring plasma environment around spacecraft.

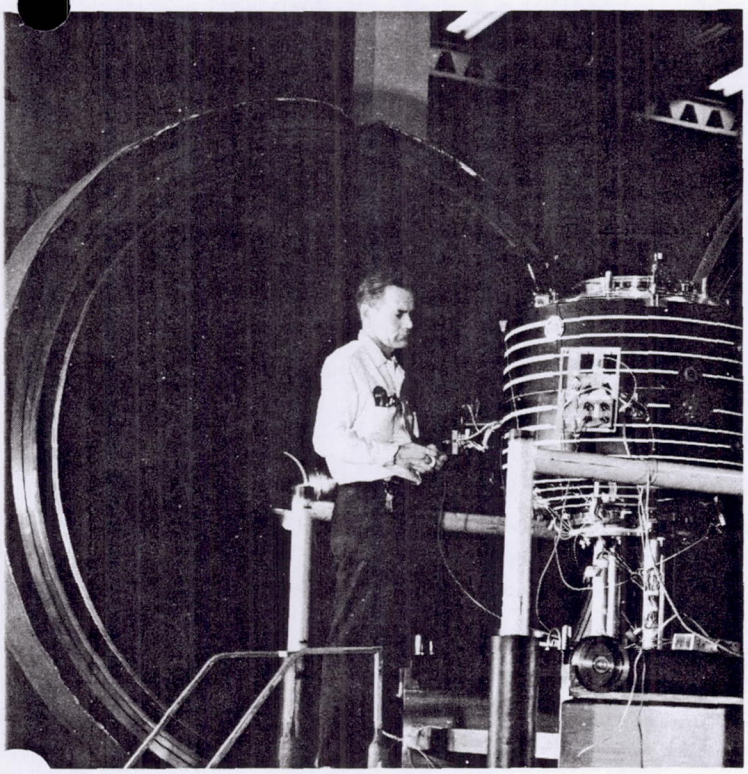
Project Results – Explorer XXXVIII was launched on July 4, 1968 from Vandenberg AFB into temporary elliptical orbit. Apogee motor was ignited 3 days later, achieving a 3636/3641-mile orbit at 120.8° inclination. Resulting retrograde orbit caused satellite to remain in sunlight for 6 months of the year, avoiding thermal shock of passing into and out of earth's shadow daily. Spacecraft was despun on July 8. Antennas were extended in increments, beginning on July 22, with final extensions completed October 8, 1968.

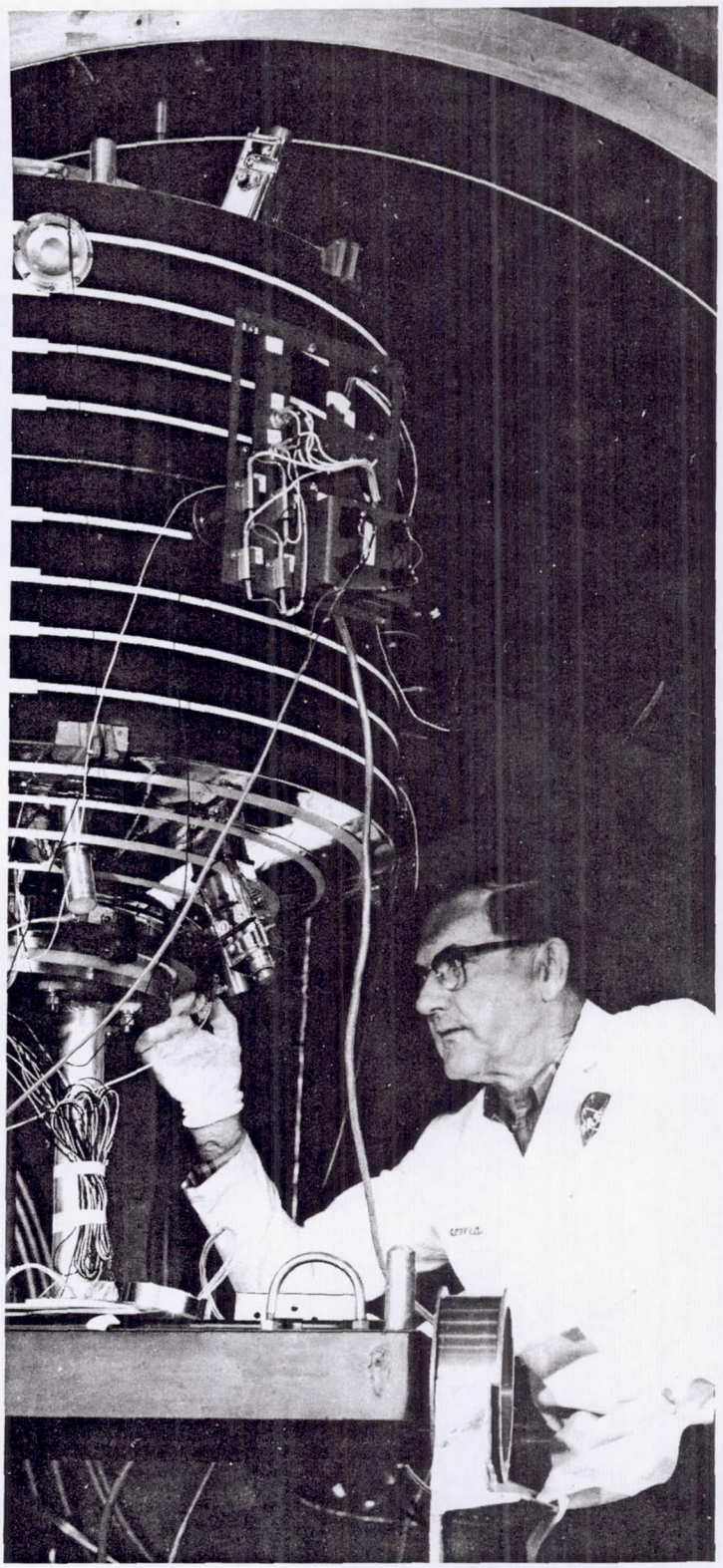


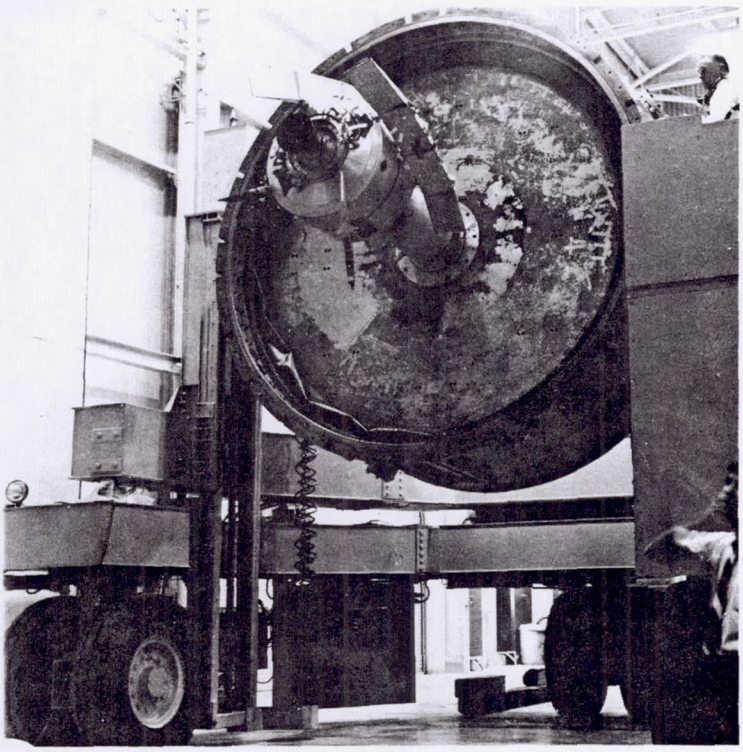
Explorer XXXVIII/Radio Astronomy Explorer-A being tested at NASA/Goddard Space Flight Center prior to launch, July 4, 1968.









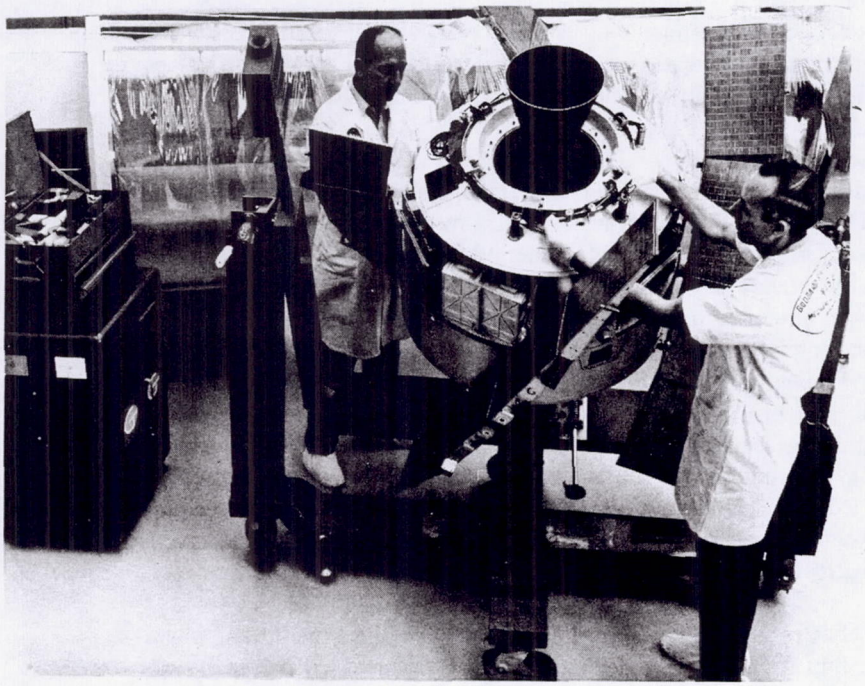


1968

Major Participants – NASA Goddard Space Flight Center, spacecraft and launch vehicle management; Fairchild Hiller, spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	J.T. Shea	NASA-GSFC
PS	R.G. Stone	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Radio Astro. 9 Freq. V	PI	R.G. Stone	NASA-GSFC
Radio Bursts Receivers	PI	R.G. Stone	NASA-GSFC
Capacitance Probe	PI	R.G. Stone	NASA-GSFC
Impedance Probe	PI	R.G. Stone	NASA-GSFC
Electron Density	PI	R.G. Stone	NASA-GSFC



Explorer XXXVIII is examined by Goddard Space Flight Center technicians prior to its launch on July 4, 1968. The objective of Explorer XXXVIII was to probe low-frequency radio signals originating in our own solar system and Earth's magnetosphere and radiation belts.



This model of Explorer XXXVIII/Radio Astronomy Explorer is being examined by Goddard engineers. The spacecraft was equipped to carry two "V" shaped antennas 750 feet long, a 120-foot long dipole antenna, and 630-foot damper booms.

EXPLORERS XXXIX AND XL (Air Density / Injun Explorer V)

Launch Vehicle – Solid-propellant Scout: 100,944-pound-thrust Algol IIB first stage; 60,764-pound-thrust Castor II second stage; 20,942-pound-thrust Antares third stage; and 5746-pound-thrust FW-4S fourth stage. First three stages inertially guided, fourth stage spin stabilized. Height: 72 feet.

Spacecraft Description – Explorer XXXIX: 12-foot polka-dotted sphere made of four alternating layers of 0.0005-inch-thick (½ mil) aluminum foil and 0.0005-inch-thick Mylar, the foil comprising the outer layer. Sphere was constructed by bonding together 40 flat triangular sections. Sphere divided at equator by a strip of plastic, allowing both metallic hemispheres to serve as antennas for tracking beacon. Inflated in orbit with nitrogen gas, which is then allowed to escape, allowing Explorer XXXIX to maintain its shape using its own rigidity. Weight: 20.8 pounds. Explorer XL: hexagonal cylinder 29 inches tall and 30 inches across widest dimensions, with outside surfaces covered by solar cells. Mounted inside and extending slightly beyond forward end was a cylindrical tube in which Explorer XXXIX was carried folded into orbit, together with ejection and inflation equipment. Appendages included five hinged booms, carried folded during launch. Weight: 157 pounds.

Project Objectives – Coordinated, dual-satellite experiment to measure particle flux and energy, VLF emissions, and atmospheric density. Measurements were to be performed at the same time and in the same general location, during active portion of solar cycle, to investigate possible correlation between energetic particle bombardment and fluctuations in upper atmospheric density.

Spacecraft Payload – Explorer XXXIX: radio tracking beacon, to supplement optical tracking, mounted inside skin along with a group of nickel-cadmium batteries. Power provided by four groups of solar cells, which were protected from radiation damage by quartz windows. Small telemeter carried to report skin temperatures, internal temperatures, and solar cell voltages. Passive thermal control provided by 4000 2.5-inch-diameter white spots made of zinc oxide paint, evenly distributed and covering about one fourth of total surface. Explorer XL: three boom-mounted antennas and two boom-mounted particle analyzers, with ten other particle sensors mounted inside, comprising four major groupings of experiments. Low Energy Proton Electron Differential Energy Analyzer (LEPEDEA) experiment included three detectors and three Geiger-Mueller tubes, measured low-energy particles down to 5 electron volts. Solid State Detector experiment included a proton-electron telescope and an alpha particle (helium nuclei) detector. VLF experiment comprised a magnetic receiver with a loop antenna carried on a 9-foot folding boom and two spherical antennas mounted on two shorter booms, measured radio emissions at frequencies between 30 Hz and 10 kHz. Spherical Retarding Potential Analyzer experiment consisted of two spherical analyzers mounted on folding booms; one recorded electrons, the other positive ions. Command and telemetry provided by command receiver, two-channel tape recorder, 250-milliwatt telemeter, and 800-milliwatt telemeter. Dry nitrogen gas system and magnetic damping rods employed for despinning and stabilization.

Project Results – Launched on August 8, 1968 from Vandenberg AFB into nearly identical orbits, Explorer XXXIX reaching a 418/1574-mile orbit at 80.6° and Explorer XL a 423/1574-mile orbit at the same inclination. Both spacecraft were operating satisfactorily.

Major Participants – NASA Langley Research Center, project management, Explorer XXXIX spacecraft management and fabrication, launch vehicle management; Univ. of Iowa, Explorer XL prime contractor; AFCRL, NASA Langley Research Center, Smithsonian Astrophysical Observatory, Univ. of Iowa, experimenters; LTV, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
Explorer XXXIX		
PM	C.W. Coffee, Jr.	NASA-LARC
CO	G.M. Keating	NASA-LARC
PS	R.F. Fellows	NASA Headquarters
SC	E.R. Schmerling	NASA Headquarters
MG	J.R. Holtz	NASA Headquarters
Explorer XL (Injun V)		
PM	J.E. Rogers	University of Iowa
PS	None Assigned	
CO	R. Brechwald	University of Iowa

Experiment	Experiment Personnel		Affiliation
Explorer XXXIX			
Nonsystematic Changes Air Density	PI	L.G. Jacchia	Smithsonian Astrophysical Observatory
Systematic Changes Air Density	PI	G.M. Keating	NASA-LARC
	OI	C.W. Coffee, Jr.	NASA-LARC
	OI	W.J. O'Sullivan, Jr.	NASA-LARC
Explorer XL (Injun V)			
L Engr Pr + El Diffeanal	PI	L.A. Frank	University of Iowa
VLF Receiver, 30Cps-16KC	PI	D.A. Gurnett	University of Iowa
	OI	L.A. Frank	University of Iowa
S.S. Det. (Proton, Elec.)	PI	J.A. Van Allen	University of Iowa
	OI	T.P. Armstrong	University of Kansas
	OI	S.M. Krimigis	Applied Physics Laboratories
Spheric. Ret. Pot. Analyzer	PI	R.C. Sagalyn	USAF Geophysics Laboratory
	OI	D.A. Gurnett	University of Iowa

ATS IV

Launch Vehicle – Atlas-Centaur: 388,000-pound-thrust Atlas first stage with two 670-pound-thrust vernier engines for roll directional control; 30,000-pound-thrust Centaur second stage. First stage radio guided, second stage inertially guided. First use of Atlas-Centaur combination for mission other than Surveyor. Height (not including payload): 107 feet.

Spacecraft Payload – Cylindrical, 72 inches long and 56 inches in diameter, with circular exterior covered by 21,864 n-on-p solar cells except for experiment band around midsection containing magnetometer sensor, ion and hydrazine gas jets. Appendages included eight quarter-wave whip antennas extended fan-like from forward end, four motor-driven gravity-gradient booms mounted inside experiment band, each extendable to 123 feet and forming a giant X when extended, and two damper booms, also mounted inside center band, each extendable to 45 feet. 6250-pound-thrust apogee motor extended from aft end. Weight (after apogee motor burnout and jettison): 864 pounds.

Project Objectives – Evaluate gravity-gradient stabilization for future synchronous operation; evaluate simultaneous transmission of voice, TV, telegraph, and digital data to several ground stations; flight test of image orthicon camera; evaluate stationkeeping capabilities of ion engine.

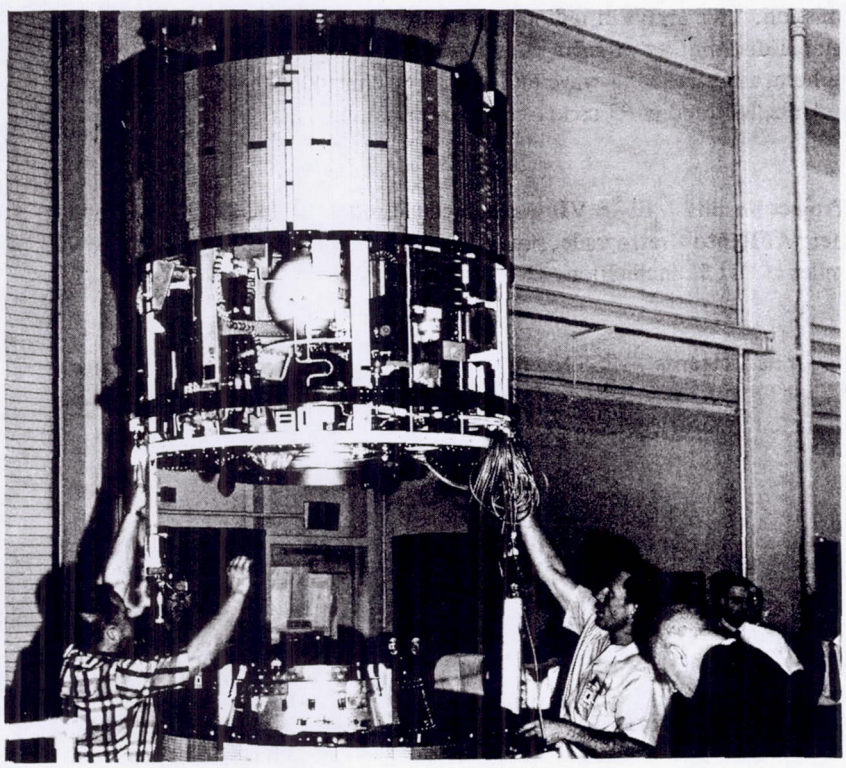
Spacecraft Payload – Gravity-gradient booms were made of thin beryllium copper strips, silver-coated, 2 inches wide and coiled like a carpenter's tape on motor driven drums, extended to form ½-inch diameter boom, each with an 8-pound weight at tip. Each pair of booms forming the X was capable of opening or closing like a pair of scissors from 11 to 30°. Each boom also carried a 9-inch disc at tip to provide focusing target for TV camera. Microwave communications experiment, carried on all ATS spacecraft to date, consisted of two microwave repeaters, two slotted waveguide planar arrays mounted flush with solar panels on earth-facing side. Image orthicon camera was a meteorological TV camera (885 lines) specifically designed for gravity-gradient stabilized spacecraft in geostationary orbit, capable of taking pictures of equatorial area 1150 miles on a side with 2-mile resolution at picture center. Ion engine experiment consisted of two 5- to 20-micropound microthruster units, each comprising a cesium contact ion microthruster, propellant storage and feed system, and control logic power conditioning unit. Telemetry data carried by four 2-watt transmitters, two encoders; command data carried by two cross-strapped receivers, two encoders.

Project Results – ATS IV was launched from Cape Kennedy on August 10, 1968. Centaur's first burn injected spacecraft into initial parking orbit of 115/475 miles at 29°. After a 61-minute coast period, Centaur failed to re-ignite for second burn, and spacecraft remained in parking orbit attached to Centaur in tumbling mode. Both ion engines were successfully operated, however, in five separate tests for a total of 23 hours. Atmospheric drag resulting from low perigee caused ATS IV to decay on October 17, 1968.

Major Participants – NASA Goddard Space Flight Center, spacecraft management; Hughes, spacecraft prime contractor; GE, Electro-Optical Systems, Hazeltine Corp., Hughes, experimenters; NASA Lewis Research Center, launch vehicle management; NASA Kennedy Space Center, launch operations; General Dynamics, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	R.J. Darcey	NASA-GSFC
PS	T.S. Aggson	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Communications Microwave Transponder	PI	Unknown	Unknown
Grav. Grad. Stabilization	PI	Unknown	Unknown
Image Orthicon (D/N) Camera	PI	J.C. Moody	NASA-GSFC
Ion Thruster, GSFC	PI	Unknown	Unknown



ATS IV was launched in Centaur's first burn injected spacecraft into initial parking orbit and remained there after a 61-minute coast period. Among ATS IV's objectives were the evaluations of gravity-gradient stabilization, simultaneous transmission of voice, TV, telegraph, and digital data.

ESSA VII

Launch Vehicle – Long-Tank Delta, but without third stage.

Spacecraft Description – Standard Tiros-ESSA configuration: hatbox-shaped 18-sided polygon, 22 inches high and 42 inches in diameter. Covered by 10,020 n-on-p solar cells. Single 18-inch receiving antenna projected from top, four 22-inch transmitting antennas extended from bottom. Two 1-inch Advanced Vidicon Camera System (AVCS) cameras mounted 180° apart on side of spacecraft. Spin stabilized at 9.2 rpm. Weight: 320 pounds.

Project Objectives – Replace ESSA VII as the primary stored data satellite in the Tiros Operational Satellite (TOS) system, providing global pictures to aid in weather forecasting and warning. Picture readout occurs at ESSA's Command and Data Acquisition Centers at Fairbanks, Alaska and Wallops Island, Virginia for transmission to ESSA's National Environmental Satellite Center where digital mosaics are projected on maps and distributed internationally.

Spacecraft Payload – Two 1-inch AVCS cameras, programmed to take 800-line pictures every 260 seconds while satellite is in daylight. From 865-mile altitude, resolution was about 2 miles per scan line at picture center, with each picture covering an area of about 2000 miles on a side. Each picture was retained by the layer on face of vidicon tube for about 7 seconds while being converted to signals for storage on magnetic tape recorder. Two cross-connected tape recorders, each capable of storing 48 frames for later transmission. Two arrays of radiometer sensors mounted 180° apart measure global distribution of solar radiation reflected by earth and earth's atmosphere, as well as long-wave radiant energy emitted by earth. Power from solar cells stored in 63 nickel-cadmium batteries.

Project Results – ESSA VII was launched on August 16, 1968 from Vandenberg AFB into a retrograde, sun-synchronous orbit ranging from 889 to 913 miles at 101.7° inclination. One AVCS has failed.

Major Participants – ESSA, project management; NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.

AURORA/ESRO I

Launch Vehicle – Scout: same as that used for Explorers XXXIX and XXXX.

Spacecraft Description – Cylindrical body with shallow truncated cones at each end, 60 inches in height and 30 inches in diameter, with surface covered by solar cells except for band around middle. Three experiment booms, one 20 inches long extended from top along spin axis, two others 39 inches long extending from bottom of spacecraft perpendicular to spin axis. Four telemetry antennas extended from top rim. Weight: 185 pounds.

Project Objectives – Measure energies and pitch angles of particles impinging on polar ionosphere during magnetic storms and quiet periods. Effects to be measured included production of visible light during auroral events and changes in electron and ion densities and temperature distributions.

Spacecraft Payload – Eight experiments included five particle measuring experiments, one auroral photometry experiment, an ion probe, and an electron probe. Power supply of 23 watts provided by 7120 solar cells and 16-cell battery. Telemetry system employed low-power transmitter (0.2 watt, 136-137 mHz) for continuous data transmission, high-power transmitter (1.2 watts, 136-137 mHz) for real-time transmission and for 3-minute playback of the single tape recorder. Spacecraft initially spin-stabilized at about 148 rpm, then despun to 1 rpm by yo-yo mechanism housed in narrow band around middle. Final despinning and stabilization accomplished by magnetic system.

Project Results – Launched from Vandenberg AFB on October 3, 1968 into a 161/949-mile orbit at 93.7°. All systems were reported performing nominally.

Major Participants – European Space Research Organization, spacecraft management; Laboratoire Central de Telecommunications, spacecraft prime contractor; Radio and Space Research Station (Slough, U.K.), Kiruna Observatory (Sweden), Bergen Univ., Norwegian Defense Research Establishment, Norwegian Institute of Cosmic Physics, University College (London), experimenters; NASA Kennedy Space Center (Western Test Range Office), prelaunch support; NASA Langley Research Center, launch vehicle management; LTV, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	D.E. Mullinger	ESA-ESTEC
PM	H.L. Eaker	Unknown
PS	R. Jaeschke	Unknown
PS	L.H. Meredith	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Part. Scint. + Pha Elec.	PI	R. Dalziel	Appleton Laboratory
	OI	O.F. Petersen	Elektronik Centralen
Electrostat Analyzer E + P	PI	W. Reidler	Kiruna Geophysical Institute
3 S.S. Part. Det.,	PI	F. Soraas	University of Bergen
	OI	O.E. Petersen	Elektronik Centralen
4 Geiger Mueller Counters	PI	O.E. Petersen	Elektronik Centralen
Proton Scint. Telescope	PI	R. Dalziel	Appleton Laboratory
	OI	O.E. Petersen	Elektronik Centralen
Auroral Photometer	PI	A.A. Egeland	Norwegian Institute of Cosmic Physics
Langmuir Probes	PI	A.P. Willmore	University of Birmingham
Ion Comp. + Temp.	PI	Unknown	Unknown

APOLLO VII

Launch Vehicle – Saturn IB (AS-205): S-IB first stage containing eight H-1 engines producing a total first stage thrust of 1.6 million pounds; S-IVB second stage containing a single J-2 engine at 200,000 pounds of thrust. S-IVB incorporated new propellant lines to prevent early shutdown 21 feet 8 inches in diameter mounted atop second stage, contained electrical and mechanical equipment for guiding, controlling, and monitoring vehicle performance from liftoff until S-IVB/CSM separation (in the case of Apollo VII, a 25-minute period of manual control was programmed to occur prior to S-IVB/CSM separation). S-IB height: 80.2 feet; S-IVB height: 58.4 feet. Total height including Launch Escape System: 224 feet.

Spacecraft Description – Launch Escape System (LES), Command Module (CM), Service Module (SM), and Spacecraft Lunar Module Adapter (SLA). *No Lunar Module or Lunar Test Article was carried on Apollo VII. LES* comprised an open-frame tower structure mounted atop CM, three solid-propellant motors: a 155,000-pound-thrust main LES motor, a 33,000-pound thrust tower jettison motor, and a 3,000-pound-thrust pitch control motor for bending CM trajectory away from launch vehicle and pad area in case of abort. Two canard vanes located near top of tower for turning CM heatshield forward. Boost protective cover, composed of glass, cloth, and honeycomb, attached to base of LES to protect CM from exhaust gases. Height: 33 feet; weight: 8900 pounds. CM: a cone-shaped pressure vessel 12 feet high and 12 feet 10 inches in base diameter, encased in heatshields and consisting of three compartments. Forward compartment contained two negative pitch reaction control engines and components of earth landing system; crew compartment contained crew accommodations, controls and displays, and spacecraft systems; aft compartment housed ten reaction control engines and fuel tankage. Heatshields made of brazed stainless steel honeycomb filled with phenolic epoxy resin as ablative material, with thickness ranging from 0.7 to 2.7 inches, according to anticipated heat loads. CM inner structure made of aluminum honeycomb sandwich-bonded between sheet aluminum alloy, ranging in thickness from 0.25 inch at forward access tunnel to 1.5 inches at base. Weight of CM: 12,659 pounds. SM: a cylinder 12 feet 10 inches in diameter by 22 feet long, with outer skin formed of inch-thick aluminum honeycomb panels, and interior divided into six sections by milled aluminum radial beams. The six sections contained fuel cells and on-board consumables, and fuel and oxidizer tankage for service propulsion system and reaction control system. Weight of SM: 19,730 pounds. SLA: a truncated cone tapering from 260 inches diameter at base to 154 inches at forward end, where it mated with SM, with walls made of 1.75-inch thick aluminum honeycomb. On Apollo VII, SLA served as structured interstage between IU and SM. Weight of SLA: 3800 pounds.

Project Objectives – First manned flight of the Apollo spacecraft included examination of combined operation of Saturn IB, Apollo CSM, and Manned Space Flight Network. Early objectives included manual control of the S-IVB prior to separation, then separation and simulated docking (using the SLA as a target), followed by operational checkouts of environmental control, guidance and navigation, and service propulsion systems, and subse-

quent rendezvous with the S-IVB. Five experiments were performed: two photographic exercises – one of terrain, the other of global and local weather systems – and three medical experiments involving pre- and post-flight examinations to determine bone demineralization, cellular changes in blood, and changes in lower body negative pressure.

Spacecraft Payload – Command Pilot Walter M. Schirra, 45; Donn F. Eisele, 38; Walter Cunningham, 36. Photographic equipment included 70 mm Hasselblad still camera and two 16 mm Maurer sequence cameras, together with color and black and white film, window mounting brackets, mirror attachments, ultraviolet filter, as well as a 4.5-pound hand-held TV camera equipped with 160- and 9-degree lens. Spacecraft systems: guidance, navigation, and control system included inertial measuring unit and associated power and data components, digital computer and associated display and keyboard panels, scanning telescope, sextant for celestial or landmark navigation. Stabilization and control system backed up guidance system, provided displays for crew-initiated maneuvers; consisted of attitude reference, attitude control, and thrust vector control subsystems. Thrust for large velocity changes and de-orbit burn provided by service propulsion system – a gimbal-mounted 20,500-pound-thrust hypergolic engine using nitrogen tetroxide oxidizer and a 50-50 mixture of unsymmetrical dimethyl hydrazine and hydrazine fuel. SM reaction control system contained four identical quads of four 100-pound-thrust hypergolic engines, mounted 90 degrees from one another near top of SM. CM reaction control system consisted of two independent six-engine subsystems of 94 pounds thrust each; one subsystem used for attitude control during re-entry, the other maintained for backup. Helium pressurized, hypergolic propellants were monomethyl hydrazine fuel and nitrogen tetroxide oxidizer. Three 31-cell Bacon-type hydrogen-oxygen fuel cell power plants located in SM provided 28-volt DC power, together with three 28-volt DC zinc-silver oxide main storage batteries, two pyrotechnic batteries, and three 115-200-volt 400-cycle three-phase AC inverters powered by main 28-volt DC bus. Environmental control system regulated spacecraft atmosphere, pressure, temperature; managed water. Telecommunications provided by PCM telemetry for relaying crew and spacecraft systems data to Manned Space Flight Network, VHF/AM and unified S-band tracking transponder, air-to-ground voice communications, onboard television. Landing system and recovery aids included drogue and main parachutes, swimmer interphone connections, sea dye marker, flashing beacon, VHF recovery beacon and transceiver, compressor-inflated bags to turn spacecraft upright in case of landing apex down.

Project Results – Apollo VII was launched from Cape Kennedy on October 11, 1968 into a 142/177-mile orbit at 31.64°. All mission objectives were met including rendezvous with and separation from S-IVB second stage in simulated rescue operations. All spacecraft systems were successfully tested under operational conditions. Among eight SPS burns was a 66-second burn on eighth day – longest to date. No serious difficulties were encountered; problems included dropout of AC bus from spacecraft electrical system, reduced performance in battery charger, deteriorating water vented to space –

which interfered with optical navigation fixes. Head cold developed by astronaut Schirra soon spread to Eisele and Cunningham, led to decision not to wear helmets during re-entry and splashdown so as to allow crew to equalize pressure on ear drums as cabin pressure changed during descent. Splashdown occurred at 27°32.5′N, 64°4′W after logging 163 revolutions, 260 hours in flight. Following splashdown, spacecraft rolled over in a nose-down position, submerging recovery antennas and hampering efforts to locate spacecraft; crew was forced to use flotation bags. Visual contact was made 22 minutes after splashdown.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell, spacecraft prime contractor, Command and Service Module; NASA Marshall Space Flight Center, launch vehicle management; Chrysler, first stage prime contractor; McDonnell Douglas, second stage prime contractor; IBM, Instrument Unit; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, Manned Space Flight Network management.

Experiment	Experiment Personnel	Affiliation
Earth-Cloud Photography	PI R.J. Allenby, Jr.	NASA Headquarters

PIONEER IX, TETR 2

Launch Vehicle – Thrust Augmented Improved Delta (TAID): same as that used for Explorer XXXVIII.

Spacecraft Description – Pioneer IX: same basic configuration as Pioneers VI, VII, and VIII – cylinder 37 inches in diameter and 35 inches high, with sides covered by solar cells except for narrow circular band around middle containing apertures for four experiments and five sun sensors. Three 64-inch booms deployed at 120-degree intervals from circular band, 52-inch command and telemetry antenna extended from center of one end, experiment antenna mounted on rim of the other end. Spacecraft structure primarily aluminum. Spin stabilized at 60 rpm. Weight: 148 pounds. TETR 2: similar to its predecessor TTS 1 – octahedron 11 inches on a side, with solar cells covering each of the eight sides. Top apex supported an S-band antenna with mast; VHG transmitter antenna sections extended from two opposing apexes in center plane; launch and ejection fitting mounted at bottom apex. Also located near bottom apex was the VHF command telemetry antenna section. Weight: 40 pounds.

Project Objectives – Pioneer IX: acquire additional data on solar plasma, energetic particles, and magnetic fields propagated by sun toward earth, for use in studying solar processes, interplanetary medium, and effects of solar activity on earth's environment. Like Pioneer VI – and unlike Pioneer VII and VIII – intended to fly an "in" mission inside earth's orbit. TETR 2: orbiting target for a series of tracking and communications exercises by ground stations of NASA's Manned Space Flight Network.

Spacecraft Payload – Pioneer IX: eight experiments included an improved three-axis magnetometer, mounted on one of the radial booms, which continuously measures strength and direction of interplanetary magnetic field in three axes, and two sets of collector plates and instruments to measure the solar wind, cosmic ray particles, electron density, electric fields, and cosmic dust. A new celestial mechanics experiment tracked data from all of the Pioneers to refine measurements of the earth-moon ratio, sun-earth distance, and planet orbits, and checked the theory of general relativity. Cosmic ray telescope similar to that carried on Pioneer VIII which made the first measurements of fluorine among galactic cosmic ray particles. Electric field experiment was also similar to that flown on Pioneer VIII, which found very large waves in the solar wind. Communications maintained by two-way S-band at about 2300 mHz utilizing two radio receivers, two command decoders, command distribution unit. Attitude control supplied by nitrogen gas jet at the end of one of the radial booms, with thrusts timed by a sun sensor, and wobbling rotation eliminated by flexibility of all three radial booms and by a damper consisting of two small balls in two cylinders at the end of one boom. Power supply of 60 watts supplied by 10,368 silicon n/p solar cells. Passive heat control achieved by heat-reflective coatings on exterior; active control provided by 20 spring-actuated louvers at spacecraft base. TETR 2: S-band transponder, receiving at 2101.8 mHz and transmitting at 2282.5 mHz. Signals contain ranging, telemetry, voice, and biomedical information

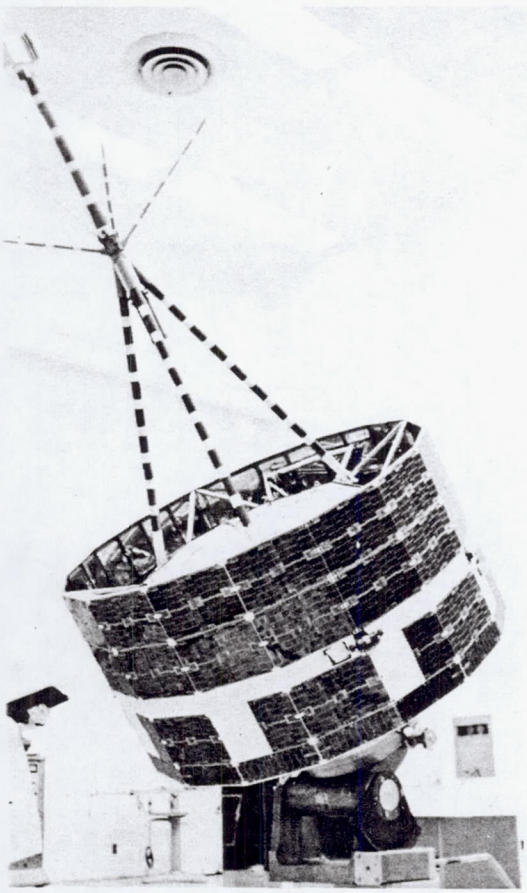
to simulate data that would ordinarily emanate from Apollo spacecraft. Satellite Tracking and Data Acquisition Network (STADAN) stations were responsible for triggering the transponder and for placing it in standby status when not in use; Manned Space Flight Network stations conducted the exercises. Electrical power furnished by rechargeable battery and some 900 solar cells. Magnetically stabilized.

Project Results – Pioneer IX and TETR 2 were launched from Cape Kennedy on November 11, 1968. TETR 2 was ejected from its cannister aboard the Delta second stage into a 232/587-mile orbit at 32.8°. Transponder was exercised by ground stations in first pass over U.S. and continued to operate successfully. Pioneer IX's sun orientation was accomplished automatically, followed by earth orientation 2 days later. Booms were deployed, and all systems were reported performing nominally.

Major Participants – NASA Ames Research Center, Pioneer VIII spacecraft management; NASA Goddard Space Flight Center, TETR 2 spacecraft management; TRW, Pioneer VIII and TETR 2 spacecraft prime contractor; JPL, NASA Ames Research Center, NASA Goddard Space Flight Center, Stanford Univ., TRW, Univ. of Adelaide, Univ. of Minnesota, experimenters; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
Pioneer IX		
PM	C.F. Hall	NASA-ARC
PS	J.H. Wolff	NASA-ARC
CO	R.R. Nunamaker	NASA-ARC
CO	N.J. Martin	NASA-ARC
CO	N.A. Renzetti	NASA-JPL
CO	A.J. Siegmeth	NASA-JPL
MG	F.D. Kochendorfer	NASA Headquarters
SC	A.G. OPP	NASA Headquarters
TETR 2		
PM	C.H. Underwood	NASA-GSFC

Experiment	Experiment Personnel	Affiliation
Pioneer IX		
3-Axis Fluxgate Magnetometer	PI C.P. Sonett	University of Arizona
	OI D.S. Colburn	NASA-ARC
Electrostatic Analyzer	PI J.H. Wolfe	NASA-ARC
	OI D.D. McKibbin	NASA-ARC
Two Frequency Beacon	PI V.R. Eshleman	Stanford University
	OI T.A. Croft	SRI International
	OI H.T. Howard	Stanford University
	OI R.L. Leadabrand	SRI International
	OI R.A. Long	SRI International
	OI A.M. Peterson	Stanford University
Cosmic Dust Detector	PI O.E. Berg	NASA-GSFC
Cosmic Ray Anisotropy	PI K.G. McCracken	CSIRO
	OI U.R. Rao	ISRO Satellite Center
	OI W.C. Bartley	National Academy of Sciences
Cosmic Ray Tele. 1MeV-1BeV	PI W.R. Webber	University of New Hampshire
Plasma Waves	PI F.L. Scarf	TRW Systems Group
	OI I.M. Green	TRW Systems Group
	OI G.M. Crook	Gaines M. Crook Associates
	OI R.W. Fredericks	TRW Systems Group
Celestial Mechanics	PI J.D. Anderson	NASA-JPL



The 238-pound Highly Eccentric Orbit Satellite (HEOS) of the European Space Research Organization undergoes pre-launch testing.

HEOS A

Launch Vehicle – Thrust Augmented Improved Delta (TAID): same as that used for Explorer XXXVIII.

Spacecraft Description – Sixteen-sided cylindrical structure 100.4 inches high and 51.2 inches in diameter, with sides covered by solar cells. Sensor boom extended parallel to spin axis, mounted on tripod at forward end, with four antennas deployed perpendicular to spin axis from apex of tripod. Length of tripod plus boom: 63 inches. Weight: 238 pounds.

Project Objectives – Study magnetic fields, cosmic radiation, and solar wind outside of earth's magnetosphere and shock wave during a period of high solar activity.

Spacecraft Payload – Eight experiments: S-16, to be conducted about 2 months after launch, involved optical observation from ground stations of an ion cloud to investigate magnetic and electric fields within magnetosphere, employed a cannister containing barium-copper oxide mixture to be ejected from spacecraft. Mixture was to be ignited about 2½ hours after ejection, releasing a cloud of barium ions and atoms which would be further ionized by solar radiation. Ground observation of cloud's motion was to yield information about magnetic field. S-24A measured magnetic fields in the range of ±64 gammas with an accuracy of 0.5 gamma, utilized three-axis magnetometer at end of boom. S-24B used telescope arrangements of Cerenkov scintillation counters to observe high-energy cosmic ray protons and to detect directional anisotropics which may be correlated with results of S-24A. S-24C observed solar protons, employed radial sensors, four-element solid-state-detector telescopes. S-58 and S-73 employed a hemispherical electrostatic analyzer and a Faraday cup to measure energy distribution and angular distribution of proton component of solar wind. S-72 measured electrons, protons, and alpha particles of solar and galactic origin, used a four-element telescope and a gas Cerenkov detector. Electrical power provided by 8576 solar cells and a 5-ampere-hour silver-cadmium battery (all systems except command receiver were to be shut down during long eclipses. Real-time telemetry system transmitted 12 bits per second, operated on 136.65 mHz at 5.5 watts. Spin stabilization regulated by nitrogen gas jets. Passive thermal design.

Project Results – HEOS A was launched from Cape Kennedy on December 5, 1968 into a 2696/13,453-mile orbit at 28.2°. All systems were reported operating nominally.

Major Participants – European Space Research Organization, spacecraft management; Junkers Flugzeug Und Motorenwerke GmbH, spacecraft prime contractor; Centre D'Etudes Nucleairs de Saclay, Imperial College (Britain), Max Planck Institute for Extraterrestrial Physics, Univ. of Brussels, Univ. of Florence and Rome, Univ. of Milan, experimenters; NASA Kennedy Space Center, launch operations management; McDonnell Douglas, launch vehicle prime contractor.

OAO II

Launch Vehicle – Atlas-Centaur: same as that used for ATS IV.

Spacecraft Description – Octagonal aluminum cylinder 10 feet long and 7 feet across, with experiments mounted in 4-foot inner cylinder running length of body, trapdoor-like sun shutter attached to top for shielding experiments from direct solar rays. With solar arrays unfolded on each side, wingspread reached 21 feet. Other appendages included two 9.5-foot balance booms extending outward one from each side at top. Weight: 4446 pounds.

Project Objectives – Observe young, hot stars in ultraviolet spectrum; observe interstellar gas; survey and produce pictorial maps of over 700 stars daily – all from the vantage point of a precisely stabilized platform above the obscuring and distorting effects of earth's atmosphere.

Spacecraft Payload – Two groups of experiments: one, a 450-pound package, contained seven telescopes to make spectrophotometric measurements in ultraviolet between 1000 and 3000Å; second experiment group weighed about 500 pounds, employed four large-aperture TV cameras with broadband photometers to scan between 1050 and 3000Å. Six gimballed star trackers, each one a small 3.5-inch reflecting telescope mounted in mechanical gimbals, provided images for conversion to error signals used to drive torque motors in gimbal axes. Stabilization provided by nitrogen gas jet system. The three-axis gyro stabilization system, added on OAO II, provided pointing accuracy of 1 minute of arc ±15 arc seconds for 50 minutes. Power system featured 10 percent greater solar cell area than on OAO I, addition of undervoltage detector, and a change from sequential to parallel charging of batteries to avoid overcharging as occurred on OAO I. Louvers were added on five electronics bays for active thermal control. Command storage doubled to 256 instructions.

Project Results – OAO II was launched from Cape Kennedy on December 7, 1968 into a near-nominal 479/485-mile orbit at 34.997°.

Major Participants – NASA Goddard Space Flight Center, spacecraft management; Grumman, spacecraft prime contractor; Univ. of Wisconsin, Smithsonian Astrophysical Laboratory, experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	J. Purcell	NASA-GSFC
PS	J.E. Kupperian, Jr.	NASA-GSFC
SC	N.G. Roman	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
4 High Resolution Telescopes	PI	F.L. Whipple	Smithsonian Astrophysical Observatory
	OI	J.F. McNall	University of Wisconsin

Experiment	Experiment Personnel		Affiliation
Stellar Photom 900-3000A	PI	A.D. Code	University of Wisconsin
	OI	R.J. Davis	Smithsonian Astrophysical Observatory
UV Phot. R Crb + Ry Sgr	PI	J.E. Gaustad	University of California, Berkeley
	OI	R.F. Knacke	University of California, Berkeley
	PI	M.F. A'Hearn	University of Maryland
UV Colors Main Sequencers	PI	G. Hill	Dominion Astrophysical Observatory
	OI	F.D.A. Hartwick	Dominion Astrophysical Observatory
	OI	J.B. Hutchings	Dominion Astrophysical Observatory
	OI	S.C. Morris	Dominion Astrophysical Observatory
	OI	G.A.H. Walker	Dominion Astrophysical Observatory
Disc. in UV Spectrum	PI	R.M. Bonnet	CNRS–SA
	OI	R. Clayrel	CNRS-LPSP
	OI	F. Praderie	Paris Observatory
UV Rad. of Rw Aur.	PI	G.H. Herbig	University of California, Santa Cruz
	OI	G. Gahm	University of California, Santa Cruz
Class. of Early Type Stars	PI	J. Borgman	University of Groningen
	OI	M. Devries	Kapteyn Observatory
Protom. of P., S. + Sey. G.	PI	T. Gehrels	University of Arizona
	OI	D.L. Coffeen	NASA-GISS
	OI	G.V. Coyne	University of Arizona
	OI	D.J. Taylor	University of Arizona
UV Invest. of CR Sources	PI	H.M. Johnson	Lockheed Palo Alto
Observation of Neptune + Jupiter	PI	M.B. McElroy	Harvard University
	OI	L.J. Wallace	Kitt Peak National Observatory
UV Observations of Planets + Com	PI	T.C. Owen	Illinois Institute of Technology
UV Enrg. Dist. of Galax	PI	T. Page	NASA-JSC
	OI	H.J. Rood	Wesleyan University
UV Spect. + Phot. Planet	PI	C. Sagan	Cornell University
	OI	B.T. O'Leary	Princeton University
UV Bright. Galac. Nucli	PI	W.G. Tifft	University of Arizona
Scan. Obs. Early Stars	PI	A.B. Underhill	University of Utrecht
	OI	J. Emming	University of Utrecht
	OI	F. Hammerschlag	University of Utrecht
	OI	H.J. Lamers	Space Research Laboratory

ESSA VIII

Launch Vehicle – Two-stage Long-Tank Delta, same as that used for ESSA VII.

Spacecraft Description – Same as ESSA VII except that APT cameras were carried instead of AVCS. Weight: 290 pounds.

Project Objectives – Provide daily coverage of local weather systems for weather stations around the world equipped with APT receivers.

Spacecraft Payload – Camera system similar to that carried on ESSA VI: two 1-inch APT cameras capable of photographing areas of about 2000 miles on a side with 2-mile resolution at picture center. APT system designed to take and transmit a picture every 352 seconds while satellite was in daylight, allowing a typical APT station to receive 8-10 pictures every day On-board triggering system programmed cameras to take pictures only when facing earth. Position and spin stabilization maintained by magnetic attitude coils. Powered by nickel-cadmium batteries and 10,020 n-on-p solar cells.

Project Results – ESSA VIII was launched from Vandenberg AFB on December 15, 1968 into a 880/910-mile orbit at 101.8° inclination.

Major Participants – ESSA, project management; NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.

INTELSAT IIIF-2

Launch Vehicle – Long-Tank Delta: modified Thor first stage at 172,000 pounds of thrust, augmented by three first stage strap-on solid-propellant Castor 1 rockets for a combined total first stage thrust of 333,500 pounds (Long-Tank Delta has the same thrust as TAID but features longer first-stage burn time); 7700-pound-thrust second stage; 5600-pound-thrust FW-4 solid-propellant third stage. Height (not including payload): 106.5 feet.

Spacecraft Description – Magnesium cylinder 41 inches tall and 56 inches in diameter, circular exterior covered with solar cells. Both aft and forward surfaces enclosed except for slight extension of apogee motor skirt aft, mechanically despun communications antenna, shaped like a cone with base cut at 45°, extending 33.6 inches forward. Overall height: 78 inches. Mounted around base of communications antenna was a doughnut-shaped omnidirectional telemetry and command antenna. Two axial thrusters mounted aft, two radial thrusters mounted at side. Earth and sun sensors mounted at side. Supporting subsystem equipment mounted inside on circular aluminum honeycomb platform. Spin stabilized at 90 rpm. Weight at liftoff: 642 pounds.

Project Objectives – Initial increment of the first global commercial communications satellite system; was to be placed in geostationary orbit over Atlantic Ocean, off coast of Brazil.

Spacecraft Payload – Communications subsystem utilized mechanically despun directional antenna and dual transponders receiving at 5930 to 6429 mHz, transmitting at 3705 to 4195 mHz; had a designed capacity of 1200 circuits, was capable of carrying up to four TV programs simultaneously. Five-year electrical power of 130 watts supplied by 10,720 solar cells, plus rechargeable 20-cell nickel-cadmium battery for periods of operation during earth's shadow. Solid-propellant 3140-pound-thrust apogee motor. Spacecraft attitude control and stationkeeping performed by two nitrogen-pressurized monopropellant hydrazine-fueled propulsion systems, each system employing a pair of tanks to supply one radial and one axial thruster.

Project Results – Launched from Cape Kennedy on December 18, 1968 into an elliptical transfer orbit. Orbit was circularized 2 days later at 22,257/22,244 miles, with an inclination of 0.71°. Spacecraft went into operation on December 24, 1968.

Major Participants – Comsat Corp., spacecraft management; TRW, spacecraft prime contractor; NASA Goddard Space Flight Center, launch vehicle management; McDonnell Douglas, launch vehicle prime contractor.

APOLLO VIII

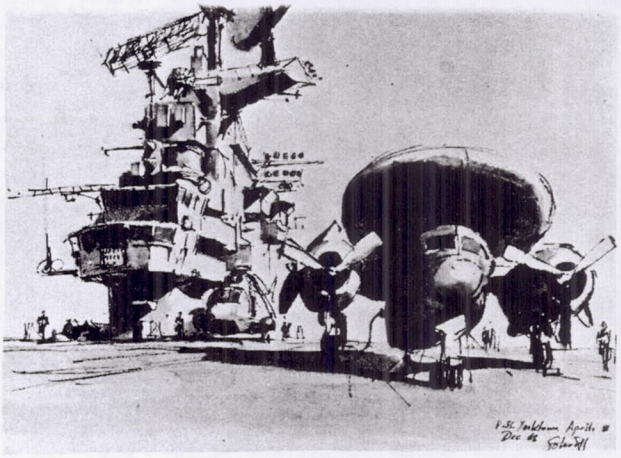
Launch Vehicle – Saturn V: S-IC first stage at 7,570,000 pounds of thrust, S-II second stage at 1,000,000 pounds of (mean) thrust, S-IVB third stage at 230,000 pounds of thrust. All three stages inertially guided. Instrument Unit, a cylinder 3 feet high and 21 feet 8 inches in diameter mounted atop third stage, contained vehicle electronics for navigation, guidance and control measurement of vehicle performance and environment, telemetry, command reception, checkout and monitoring of vehicle functions, power generation and distribution, and preflight checkout and launch. Major innovation for the flight included new helium prevalve cavity pressurization system on S-IC to clamp out pogo effect, new J-2 engines on S-IVB stage capable of 230,000 pounds of thrust, use of helium heater as repressurization system on S-IVB, early cutoff of center F-1 engine on S-IC to hold acceleration below 4 g's, software changes in Instrument Unit permitting 2-degree outward cant of outboard F-1 engines to reduce load on spacecraft in event of premature cutoff of F-1. Height: 363 feet.

Spacecraft Description – AS-503/CSM-103: Launch Escape System (LES), Command Module (CM), Service Module (SM), Spacecraft Lunar Module Adapter (SLA), Lunar Module Test Article (LTA) B. LES, CM, SM, SLA essentially identical to those used on Apollo VII. Flown for first time was the high-gain steerable S-band antenna – four 31-inch-diameter parabolic dishes mounted on folding boom at aft end of SM, deployed at right angles to longitudinal axis after S-IVB/CSM separation. Weight of LES: 8900 pounds; weight of CM: 12,392 pounds; weight of SM: 51,258; weight of SLA: 4150 pounds. LTA-B carried only for ballast.

Project Objectives – Overall mission objectives included demonstration of coordinated performance of Apollo crew, Apollo CSM, and support facilities during a manned Saturn V mission; demonstration of translunar injection; demonstration of CSM navigation, communications, and midcourse corrections, demonstration of consumables assessment and passive thermal control. Detailed test objectives were to refine systems and procedures relating to future lunar operations.

Spacecraft Payload – Command Pilot Frank Borman, 40; James Lovell, Jr., 40; William A. Anders, 35. Photographic equipment same as that carried on Apollo VII: two 70 mm Hasselblad still cameras, a 16 mm Maurer movie camera, and a 4.5-pound hand-held TV camera. Large quantity of film of various types was carried for lunar surface photos, other items of interest during course of mission. Spacecraft systems essentially identical to those carried on Apollo VII.

Project Results – Apollo VIII was launched from Cape Kennedy on December 21, 1968 into a 114/118-mile parking orbit at 32.6°. During second revolution, at 02:50:00 ground elapsed time (GET), S-IVB was restarted for a 5-minute 17-second burn, initiating translunar coast. Following S-IVB/CSM separation at 03:21:00 GET, a 1.5-fps radial burn of SM reaction control engines was initiated to establish sufficient distance for S-IVB propellant dumping. Following propellant dumping, however, which sent the stage into diverging trajectory and solar orbit, separation distance was still deemed

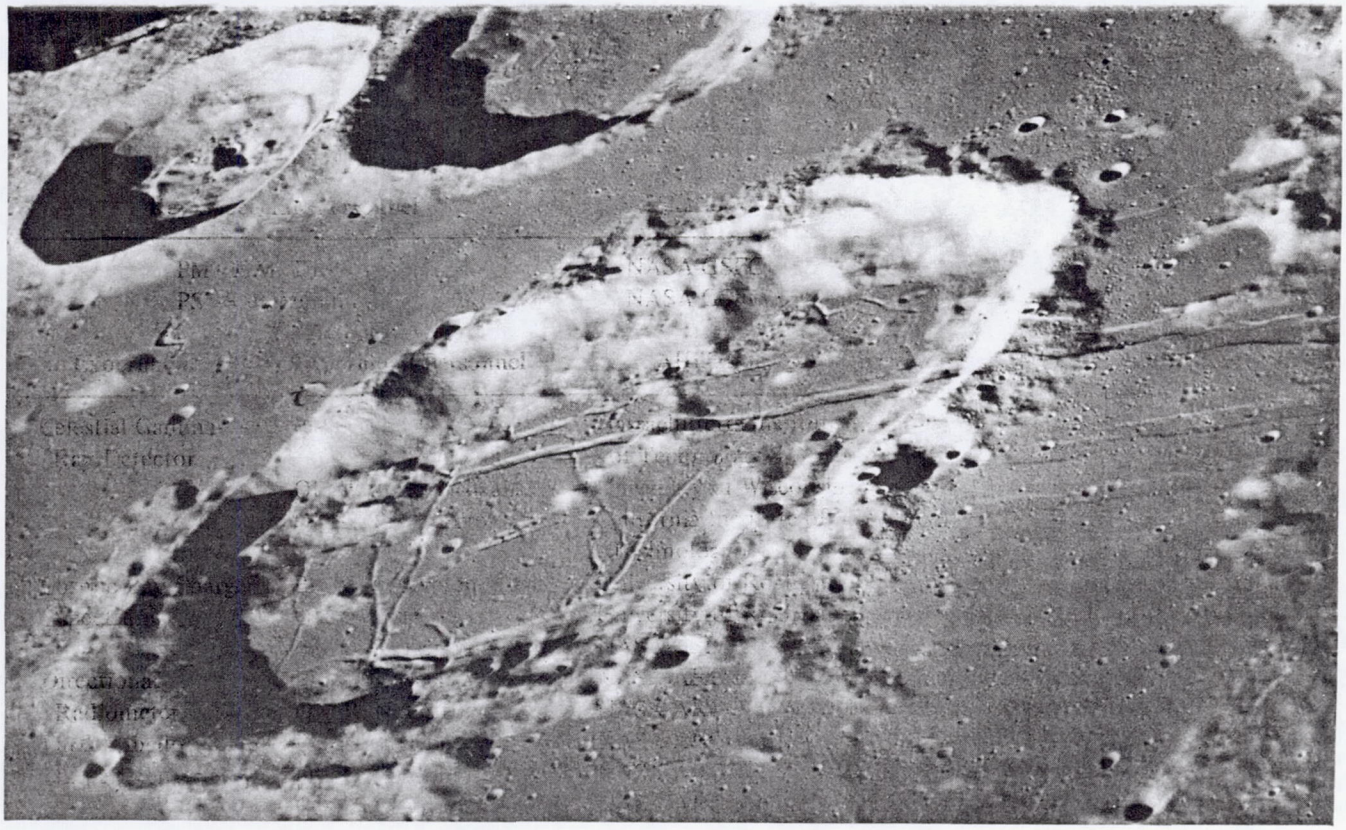


Artist's view of aircraft ready for take-off aboard the U.S.S. Yorktown, to recover Apollo VIII.

inadequate and a second SM reaction control burn of 7.7 fps was performed. First midcourse correction came at approximately 10 hours 55 minutes into the mission, provided a first check on SPS engine prior to committing spacecraft to lunar orbit insertion. Second and final midcourse correction prior to lunar orbit insertion came at 61:08:54 (two intermediate midcourse corrections were eliminated as unnecessary). Loss of signal occurred at 68:58:45, when Apollo VIII passed behind moon. First lunar orbit insertion burn, at 69:08:52, lasted 4 minutes 2 seconds, reduced spacecraft's 8400-fps velocity by 2994 fps, resulting in initial lunar orbit of 70/193 miles. Orbit was circularized at 70 miles by second lunar orbit insertion burn of 135 fps, performed at start of third revolution, again on back side of moon, at 73:35:05. During the 20-hour period in lunar orbit, crew conducted a full, sleepless schedule of tasks including landmark and landing site tracking, vertical stereo photography, stereo navigation photography, and sextant navigation. At end of 10th lunar orbit (89:19:16), a 3-minute 23-second transearth injection burn was conducted, adding 3522 fps. Only one midcourse correction, a burn of 5 fps conducted at 104:00:00, was required instead of the three scheduled. Six telecasts were conducted during the mission – two during translunar coast, two during lunar orbit, two during transearth coast – all of excellent quality. These transmissions were telecast worldwide and in realtime to all five continents. Voice communications were also exceptionally good throughout mission. Separation of CM from SM occurred at 146:31:00. Double-skip maneuver conducted during re-entry steering phase resulted in altitude gain of 25,000-30,000 feet. Entry velocity was 24,696 mph, with heatshield temperatures reaching 5000°F. Splashdown at 8°8′N, 165°W, after 147 hours 11 seconds in flight, was within 5000 yards of planned point.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell, spacecraft prime contractor, Command and Service Modules; NASA Marshall Space Flight Center, launch vehicle management; Boeing, first stage prime contractor; North American Rockwell, second stage prime contractor; McDonnell Douglas, third stage prime contractor; IBM, Instrument Unit; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, Manned Space Flight Network management.

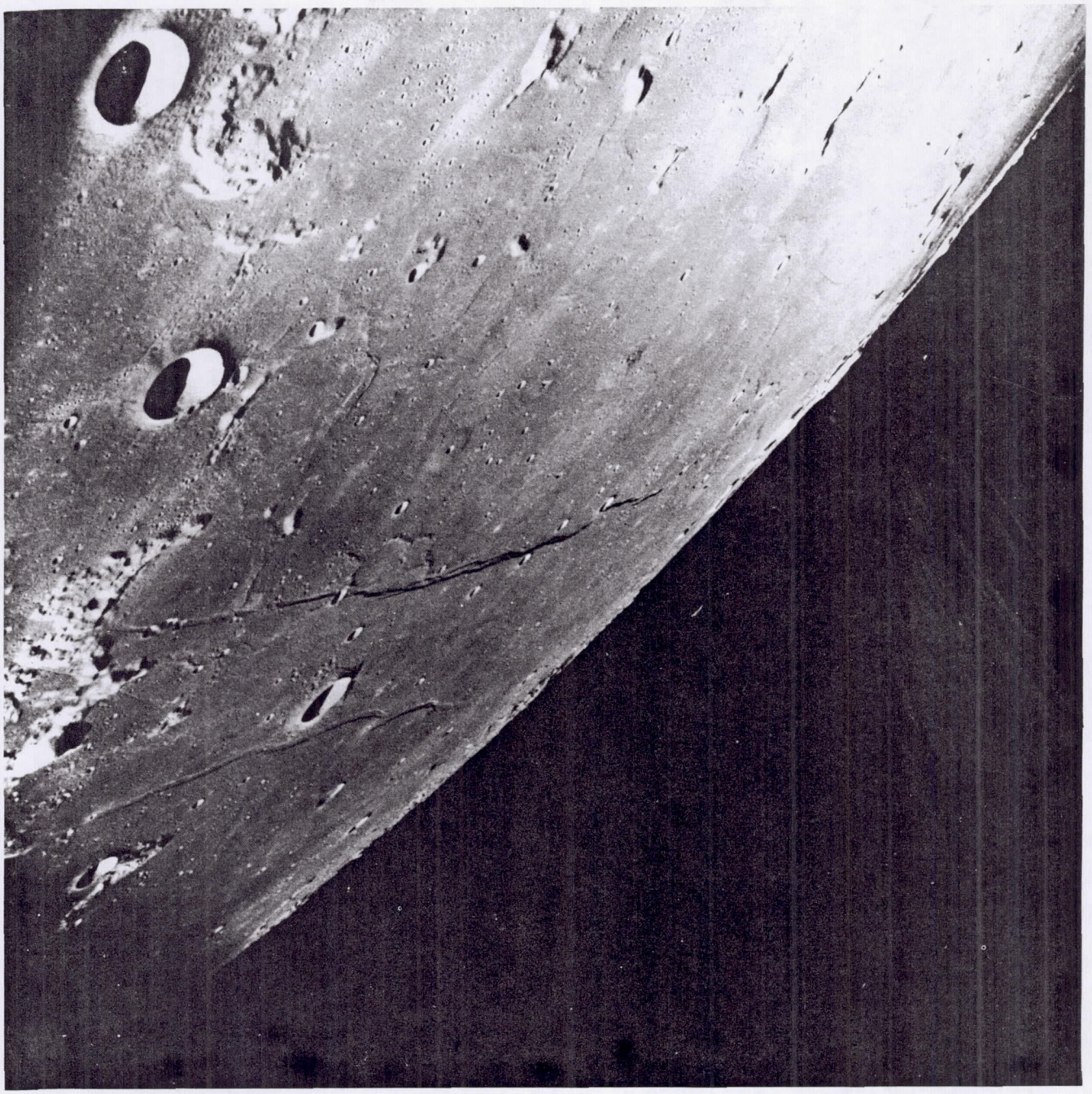
Experiment	Experiment Personnel	Affiliation
Photos 70MM + 16MM	PI R.J. Allenby, Jr.	NASA Headquarters



Looking south at the large crater Goclenius, with the prominent rille that crosses the crater rim.



Crater Langrenus is approximately 85 statute miles in diameter.



Looking into the Sea of Tranquility. The nearer feature is the Cauchy Scarp. The upper linear feature is the Cauchy Rille. The prominent crater Cauchy lies between the rille and the scarp.

APOLLO VIII PROVIDES A CLOSE-UP LOOK AT MOON

1968

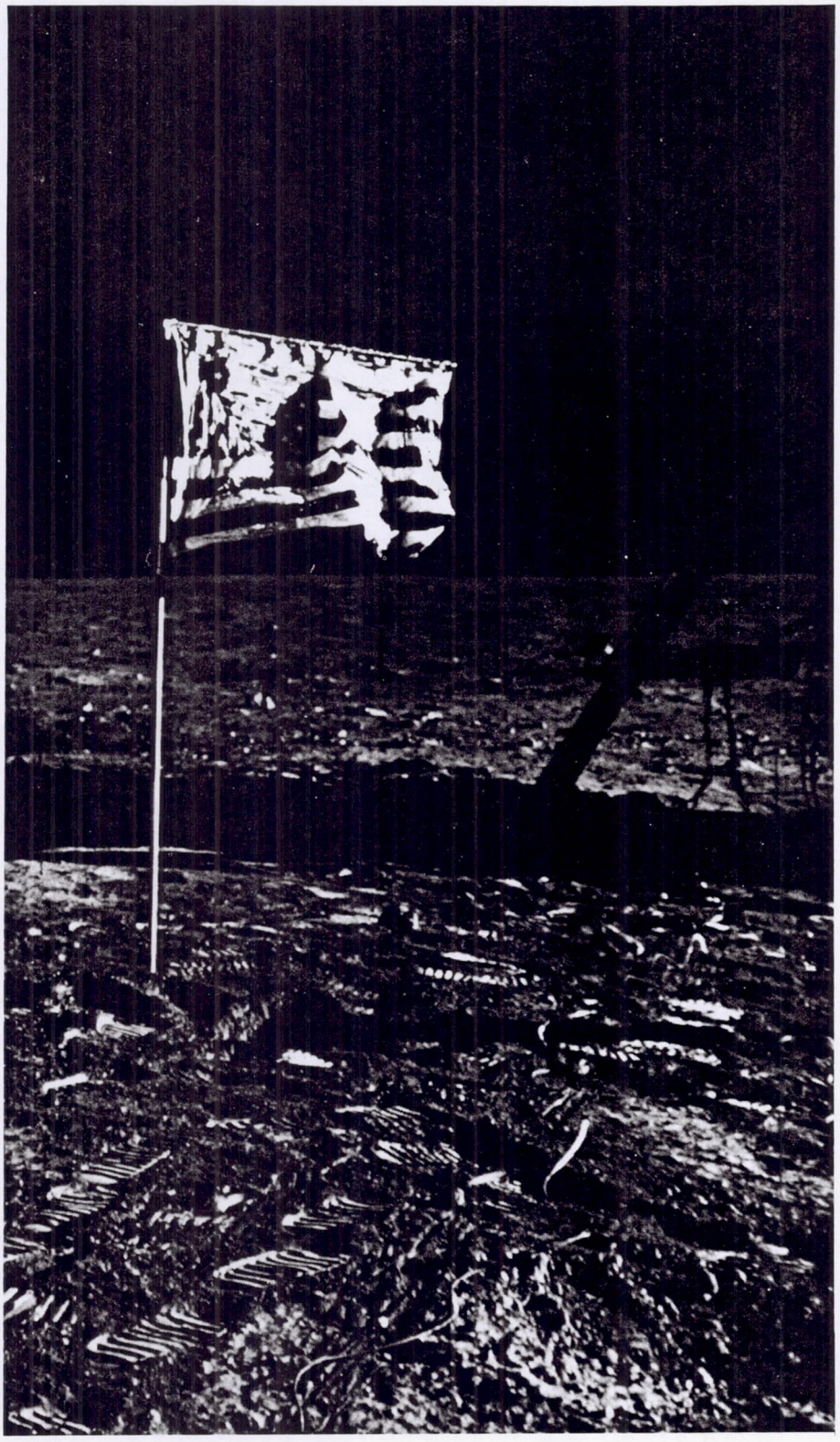
JULY 20, 1969



Astronaut Edwin "Buzz" Aldrin facing American flag placed at Sea of Tranquility shortly after lunar landing. Partial view of lunar lander on right. Photo was taken by fellow astronaut Neil Armstrong.

THE EAGLE

1969



HAS LANDED !

OSO V

Launch Vehicle – Delta: modified Thor first stage with 172,000 pounds of thrust, 7500-pound-thrust second stage, and 5600-pound-thrust third stage. Height: 92 feet.

Spacecraft Description – Same basic two-stage design as previous OSO's: overall height, 38 inches. Spinning wheel-like base, a nine-sided drum 44 inches in diameter, revolving at 30-40 rpm, allowed five experiments housed in compartments in the base section to scan the sun every two seconds. Pitch-control system maintained the base spin axis perpendicular to the sun while overall spacecraft was pointed within one-minute-of-arc accuracy. Base also held power, commands, spin-control, and communication subsystems. Overall diameter increased to 92 inches when three spin-control booms (arms) were extended for stabilization; nitrogen gas stored in spheres at end of booms were part of controls for spin rate. Upper "sail" portion, fan shaped and 23 inches high, contained directionalized instrumentation and solar cell panels, faced the sun during daytime. Magnetic bias coil augmented pitch control, saved gas consumption. Design lifetime, six months. Weight: 641 pounds.

Project Objectives – Continuation of OSO program: to study sun's X-rays, gamma rays, and radio emissions; to better understand sun's structure; determine solar influence on Earth; and obtain baselines for studying other more distant suns. Primary objective for OSO V was obtaining high spectral-resolution data, within the range of one to 1250 angstroms. Several experiments were extensions of studies begun with earlier OSO's. Concentration given to studying solar flares and serving as one source for early warning to astronauts on-board manned space flights and EVA missions. Eventual goal, using data combined from that obtained from other spacecraft programs, was to permit solar eruption predictions to provide advanced warnings of dangers to deep space or manned lunar explorations.

Spacecraft Payloads – Eight on-board experiments weighed 265 pounds. The three pointed experiments in the sail portion were: a spectrometer to monitor the X-ray ultraviolet spectrum; a spectroheliograph to study the intensity and variations of the X-ray spectrum in the ranges of 3 to 9 angstroms and 8 to 18 Å; an extreme ultraviolet spectroheliograph to monitor the extreme UV in the ranges of 1216, 304, 465, 284, 335, and 229 Å. The six experiments mounted in the wheel were: a zodiacal light telescope to measure intensity and polarization of blue and visual light regions, and the terrestrial afterglow; lyman-alpha atomic hydrogen cell to monitor self-reversal of solar lyman-alpha line; a far ultraviolet monitor to study the energy flux in three bands – 280 to 370, 465 to 630, and 760 to 1030 Å; low-energy detector to observe solar and stellar gamma ray radiation from 5 to 150 Å; an X-ray monitor for solar flux-variation studies in the ranges 0.5 to 3, 2 to 8, 8 to 16, and 0.1 to 1.6 Å; X-ray ion chambers to study soft solar X-ray flux and its subsegment hardening; and a photometer to monitor the helium II lyman-alpha 304 angstrom line, which is primarily responsible

for Earth atmosphere heating at about 124 miles up, and to provide data for aeronomy and ionospheric physics. An important innovation in this satellite as with OSO IV was the ability to perform a raster scan across the solar disk, rather than only point directly at sun's center as with OSO III. The sail operated both in a pointed mode at the solar disk center, and in the raster scan mode when it scanned the entire disk and portions of corona to azimuth angle of 40 arc-minutes, in a square pattern of 7.68 seconds per sweep taking a total of 307.2 seconds to complete. Scanning was initiated by ground command and terminated automatically by a "night" signal. Power supply of 38 watts provided by 4 square feet of 2016 n-on-p solar cells. Maximum load of 26 watts included 13 watts for experiments; about 7 watts required at night.

Project Results – OSO V was launched January 22, 1969 from Cape Kennedy into a nearly circular orbit of 333 to 349 miles at an inclination of 32.9°. All experiments functioned normally.

Major Participants – NASA Goddard Space Flight Center, spacecraft, launch vehicle, and experiment management, experimenter; Ball Brothers Research Corp., spacecraft prime contractor; University College London jointly with University of Leicester, the University of Paris, France, University of Colorado, University of Minnesota and U.S. Naval Research Laboratory, experimenters; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	J. Thole	NASA-GSFC
PS	S.P. Maran	NASA-GSFC
MG	M.E. McDonald	NASA Headquarters
SC	G.K. Oertel	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
3-9A + 8-18A Spectroheliograph	PI	R.L.F. Boyd	University College London
	OI	E.A. Stewardson	
	OI	A.P. Willmore	University of Birmingham
	OI	K.A. Pounds	University of Leicester
Solar EUV Emission Lines	PI	J.D. Purcell	US Naval Research Laboratories
	OI	C.R. Detwiler	US Naval Research Laboratories
	OI	R. Tousey	US Naval Research Laboratories
Solar UV + X-Ray Spect.	PI	W.M. Neupert	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Solar X-Ray, 0.5-60A	PI	T.A. Chubb	US Naval Research Laboratories
	OI	R.W. Kreplin	US Naval Research Laboratories
	OI	H.D. Friedman	US Naval Research Laboratories
Solar Gamma Rays 5-150 keV	PI	K.J. Frost	NASA-GSFC
	PI	H.M. Horstman	NASA-GSFC
	OI	E.D. Rothe	NASA-GSFC
Solar, Lyman Alpha Self-Revers.	PI	J.E. Blamont	CNRS-SA
	OI	P. Coufleau	Paris Observatory
Zodiacal Lgt + Terrs. Airglow	PI	E.P. Ney	University of Minnesota
Solar, UV, 280-1030A	PI	W.A. Rense	University of Colorado
	OI	R. Parker	University of Colorado
	OI	E.C. Bruner, Jr.	Lockheed Palo Alto, California
	OI	F. Wilshusen	University of Colorado

ISIS A

Launch Vehicle – Thrust-Augmented Improved Delta (TAID): same as that used for ESSA IX.

Spacecraft Description – Like Alouettes I and II, ISIS A was spherical in configuration, 50 inches in diameter, 42 inches high, its surface covered by 11,136 n-on-p solar cells. Chief difference was addition of capability for on-board data storage. Two extendable antennas, 240 and 62 feet long, sound upper ionosphere; four telemetry antennas project from the base; quadra-loop beacon antennas were mounted around the satellite equator; and two antenna-like booms support probes for several on-board experiments. Attitude control was also newly incorporated into this design; maintained by a spin-stabilization system including a three-axis magnetometer and solar-aspect sensor; magnetic torquing controls spin rate to within one to three rpm. Weight: 532 pounds.

Project Objectives – Canada became the third nation to develop a complete satellite – Alouette I, launched in September 1962 – under an agreement between the Canadian Defence Research Board and NASA's international cooperative program. Alouette I established a longevity record and after six years still continued to return useful data. Alouette II, which was launched in November 1965, and provided excellent data, initiated a joint Canadian-NASA International Satellites for Ionospheric Studies (ISIS) program. Main objective of ISIS A was to gather information on the nature (depth, composition, etc.) and behavior of upper latitude ionosphere, especially to study ionospheric "storms", disturbances, and "polar blackouts," with the goal of improving long-range radio transmissions.

Spacecraft Payload – ISIS A carried ten experiments, more complex than Alouette I (four experiments) and Alouette II (five). Experiments provided by Canada comprised swept high-frequency probe to sound the ionosphere over great distances; a fixed-frequency sounder to probe at six specific frequencies; an experiment to measure both ionospheric and extraterrestrial radio noise in the outer atmosphere; a special receiver for measuring VLF radio signals generated by lightning flashes and other natural phenomena (artificial stimulation of some of these phenomena also attempted by an on-board generator, while a VLF exciter stimulated resonances in the plasma); detectors of energetic particles to determine their production, entrance, and distortions within the magnetosphere; and a radio beacon to enable ionosphere structure measurements. Experiments provided by the U.S. include: an electrostatic probe to measure temperature and concentrations of electrons near the satellite; an ion mass spectrometer; a three-inch spherical electrostatic probe to measure positive ion numbers and density; and a detector of particles with lower energies such as those that cause visual auroral displays. Telemetry: 4-watt FM, 2-watt PCM/FM, and 4-watt 400/500 mHz bandwidth for tape recorder fast playback, or direct transmission of the sounder or VLF experiment. Programmer had 216 possible commands, five of which could be stored. Power provided by nickel-cadmium batteries.

Project Results – ISIS A was launched January 30, 1969 from Vandenberg AFB into a highly elliptical near-polar orbit of 600 by 3515 miles, at an inclination of 88.4°.

Major Participants – ISIS program was conducted jointly by the Canadian Defence Research Board and NASA. Satellite design authority and Canadian portion management: Defence Research Telecommunications Establishment. Prime spacecraft contractor: RCA Victor, Ltd., Montreal. U.S. portion management: NASA Goddard Space Flight Center. Canadian experimenters: DRTE provided four: National Research Council of Canada: University of Western Ontario. U.S. experimenters: NASA; AF Cambridge Research Laboratories; Southwest Center for Advanced Studies. Launch vehicle prime contractor: McDonnell Douglas. Launch and launch support: Western Test Range.

Key Spacecraft Personnel		Affiliation
PE	C.A. Franklin	Communication Research Centre
CO	L.H. Brace	NASA-GSFC
CO	J.H. Whitteker	Communication Research Centre
PS	L.H. Brace	NASA-GSFC
MG	F.W. Gaetano	NASA Headquarters
MG	C.A. Franklin	Communication Research Centre
PC	R.C. Langille	Communication Research Centre
PM	L.H. Brace	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Sweep Frequency Sounder	OI	J.E. Jackson	NASA-GSFC
	PI	J.H. Whitteker	Communication Research Centre
	OI	J. Turner	Ionospheric Pred Serv
	OI	M. Sylvain	LGF
	OI	O. Holt	Auroral Observatory
	OI	Y. Ogata	Radio Research Laboratory
	OI	R. Raghavarao	Physical Research Laboratory
	OI	R.B. Norton	NOAA-ERL
	OI	C.E. Petrie	Communication Research Centre
	OI	K.L. Chan	NASA-ARC
	OI	R.S. Unwin	Department of Science and Industrial Research

Experiment	Experiment Personnel		Affiliation
Fixed Frequency Sounder	PI	W. Calvert	Lockheed Palo Alto
	OI	R.B. Norton	NOAA-ERL
	OI	J.M. Warnock	NOAA
	OI	J.H. Whitteker	Communication Research Centre
	OI	C.E. Petrie	Communication Research Centre
VLF Experiment	PI	R.E. Barrington	Communication Research Centre
	OI	F.H. Palmer	Communication Research Centre
Energetic Particle Detectors	PI	I.B. McDiarmid	National Research Council of Canada
	OI	J.R. Burrows	National Research Council of Canada
	OI	R. C. Rose	National Research Council of Canada
E + P Spectr, 10-10000 EV	PI	W. J. Heikkila	University of Texas, Dallas
Ion Mass Spect, 1-20 A MV	PI	R.S. Narcisi	USAF Geophysics Laboratory
Cyl. Electrostatic Probe	PI	L.H. Brace	NASA-GSFC
	OI	J.A. Findlay	NASA-GSFC
Spher. Electro. Analyzer	PI	R.C. Sagalyn	USAF Geophysics Laboratory
	OI	M. Smiddy	USAF Geophysics Laboratory
Radio Beacon	PI	P.A. Forsyth	Western Ontario University
	OI	G.F. Lyon	Western Ontario University
	OI	E.H. Tull	Western Ontario University
Cosmic Radio Noise	PI	T.R. Hartz	Communication Research Centre

INTELSAT III F-3, III F-4

Launch Vehicle – Long Tank Thrust-Augmented Delta: modified Thor first stage at 172,000 pounds of thrust augmented by three first stage strap-on solid-propellant Castor I rockets for a combined total first stage thrust of 333,500 pounds (Long Tank Thrust-Augmented Delta had the same thrust as TAID but featured longer first-stage burn time); 7800-pound-thrust second stage; 5700-pound-thrust FW-4 solid propellant third stage. Height 106.3 feet.

Spacecraft Description – Both satellites identical; each a magnesium cylinder 41 inches tall and 56 inches in diameter; exterior covered with solar cells. Aft and forward surfaces enclosed except for slight extensions of apogee motor skirt aft, and mechanically despun communications antenna, shaped like a cone with base cut at 45°, extends 33.6 inches forward. Overall height: 78 inches. Mounted around base of communications antenna was a doughnut-shaped omnidirectional telemetry and command antenna. Two axial thrusters mounted aft, two radial thrusters mounted at side. Earth and sun sensors mounted at side. Supportive subsystem equipment mounted inside on circular aluminum honeycomb platform. Spin stabilized at 90 rpm. Weight, nominal 322 pounds in orbit, then weighing 317 pounds due to expenditure of additional apogee motor propellants when repositioned to orbit over Indian Ocean.

Project Objectives – Intelsats III F-3 and III F-4 were second and third increments of the first operational commercial communication satellite system. Spacecraft III F-3 was to be placed over the Pacific Ocean. Satellite III F-4 was a subsequent replacement for III F-3 when the latter developed a minor malfunction and thereupon was repositioned to handle traffic loading over the Indian Ocean, thus completing early implementation of worldwide coverage.

Spacecraft Payload – Identical except for identifying beacon signals; communication subsystem on each utilizes mechanically despun antenna and dual transponders receiving at 5920 to 6420 mHz, transmitting at 3695 to 4195 mHz. Satellites had a design capacity of 1200 circuits each, and each capable of carrying up to four TV programs simultaneously. Each spacecraft had a five-year-lifetime electrical power system providing 130 watts generated by 10,720 solar cells; system also had a rechargeable 20-cell nickel-cadmium battery for satellite operation when in the Earth's shadow. A solid-propellant 3140-pound-thrust apogee motor was used to inject the satellite into synchronous orbit. Attitude control and stationkeeping were performed by two nitrogen-pressurized monopropellant hydrazine-fueled propulsion systems, each system employing a pair of tanks to supply one radial and one axial thruster.

Project Results – Intelsat III F-3 was launched from Cape Kennedy on February 5, 1969 into an elliptical transfer orbit, which was circularized two days later when the apogee motor was fired, to an orbit of 22,215 by 22,235 miles, at an inclination of 1.29°. Spacecraft went into operation

on February 16, 1969. In March, one stage of a two-band tunnel diode amplifier was lost, which resulted in the loss of 16 db on the one band. Accordingly, the decision was reached to utilize this spacecraft, instead of a later one, to serve the traffic over the Indian Ocean, since its capacity was far more than sufficient for handling traffic loading in that area. Intelsat III F-4 that replaced III F-3 over the Pacific contained a redundant subsystem to preclude a similar malfunction, as do the later Intelsat III's. Subsequently, after the launch of III F-4, satellite III F-3 was moved to 62.5°E Long. over the Indian Ocean. Intelsat III F-4 was launched from Cape Kennedy on May 22, 1969 into an elliptical orbit and similarly had its orbit nearly circularized to 21,889 by 22,166 miles, with an inclination of 0.5°. Spacecraft went into operation in early June 1969 over the Pacific, at 174°E Long.

Major Participants – Comsat Corp., spacecraft management; TRW, spacecraft prime contractor; NASA Goddard Space Flight Center, launch vehicle management; McDonnell Douglas, launch vehicle prime contractor.

MARINER VI AND VII

Launch Vehicle – Same for both spacecraft. Atlas-Centaur – its first use for interplanetary missions: 395,000-pound-thrust Atlas first stage (including two 670-pound-thrust vernier engines for roll directional control); 30,000-pound-thrust Centaur second stage. Both stages inertially guided. Height 123 feet.

Spacecraft Description – (Mariner VI and VII spacecraft identical.) Base structure was a 37-pound octagonal forged-magnesium frame, 54.5 inches diagonally and 18 inches deep, containing eight subsystem compartments that also provided structural strengthening. Four solar panels 84 inches long and 35.5 inches wide attached to the top; each panel had 20.7 square feet of solar cells (83 square feet total, each spacecraft); when deployed, they spanned 19 feet. Attitude control jets mounted at panel tips. Low-gain omnidirectional antenna mounted atop four-inch-diameter aluminum tube, which served as a waveguide and extended 88 inches from the top of the base. Cone-shaped thermal control flux monitor also mounted at top of mast. Total height, 11 feet from top of low-gain antennas mast to bottom of lower experiment-mount scan platform. Weight 910 pounds.

Project Objectives – Primary mission objectives for both Mariner VI and VII Mars 1969 flybys were the scientific study of the surface and search of extraterrestrial life, and to develop technologies for future Mars missions. Flights also to further demonstrate engineering concepts and techniques required for long-duration flight away from the sun. Flight duration and distance for Mariner VI to be 156 days and 226 million miles; for Mariner VII, 133 days and 193 million miles; communication distance to Earth during planetary encounters of each spacecraft to be, respectively, 59.5 million miles (about 5.5 light-minutes) and 61.8 million miles. Both Mariners to fly by Mars at about 2000 miles – Mariner VI to pass over the Mariner equator on July 31, 1969, concentrating on a belt roughly 90° East of the 1965 photo path of Mariner VI. Mariner VII to overfly the southern hemisphere near the South polar cap on August 5, 1969, after overlapping the Mariner VI path over the permanently dark area near the equator. Whereas Mariner IV's photos covered 600,000 square miles (1%) of the planet's surface, Mariner VI and VII far-encounter photos were to cover all of the planet as it rotated twice for each set of cameras on both vehicles; also, closeups were to be made of about 20 percent of the planet's surface. Best-resolution of the approach-phase TV pictures to be 15 miles, versus 100-mile-limit from Earth; highest resolution in surface pictures about 900 feet, versus two miles for Mariner IV.

Spacecraft Payload – Both Spacecraft identical. Two television cameras: Camera A, for medium-resolution (wide-angle) approach pictures, equipped with red, green and blue filters to delineate corrected-color differences of the planetary atmosphere and surface; Camera B, for high-resolution (narrow-angle) pictures, programmed to overlap specific areas within regions studied by Camera A, equipped with a yellow filter to reduce the effects of planetary atmospheric haze, and with a modified Schmidt Cassegrain telescope to be used for approach pictures. Camera A similar to the camera flown on Mariner IV, but with a wide-angle lens to cover an area 12 to 15 times larger than for Mariner IV yet with the same two-mile resolution quality. Camera

B's optical resolution 10 times sharper than Camera A and designed to cover an area 100 times larger on the Martian surface. Alternate camera operation, each taking one picture every 42.25 seconds within the experiment range of 6000 to 2000 miles. Improved vidicon tubes with 704-line resolution used to store and transmit images. Cameras mounted on scan platform, movable on Earth command 215° clockwise and 64° conically. Cameras capable of focus adjustments to account for surface altitude variations up to 8.3 miles. Other experiment packages, which together with cameras were mounted on motor-driven, two-degree-of-freedom scan platform below the octagonal base, included the following: Infrared radiometer (IRR) to perform thermal mapping, overlapping the areas covered by TV experiments; two detectors in each instrument to provide 30 readings, one every 63 seconds; one detector to operate in the range near 300°K, the other around 140°K. IRR's on both spacecraft to scan the Martian surface from late morning to late evening, yielding cooling rates and indices of surface compositions, especially valuable from the dark side not seen by Earth. Chemical constituents of upper atmosphere (60 to 600 miles) to be identified and measured, as well backup density and temperature data to be provided, by an ultraviolet spectrometer operating in the range from 1000 to 4300 angstroms in 3-second sweeps; the first attempt to use this technique to identify Martian atmospheric gases. Lower atmosphere and surface compositions to be measured by an infrared spectrometer (IRS), to scan in the 1.9 to 14.3 microns wavelength range with one reading every 10 seconds. Celestial mechanics experiment to be performed also, using radio signals during flight, at encounter, and the flight behind and beyond Mars; objectives included determining the mass of Mars, Earth-Mars distance at encounter, and the Earth-Moon mass ratio. Occultation experiment utilized S-band radio signals from the spacecraft, to obtain precise measurements of the radius of Mars, the reflection of radio signals from the planet's surface, and the electron density of its atmosphere. Primary contents of the eight compartments in base of each spacecraft were: (1) power conversion equipment; (2) midcourse correction propulsion system; (3) central computer and sequencer and attitude control subsystem; (4) telemetry and command subsystem; (5) tape recorders; (6) radio receiver and transmitter; (7) science instrument electronics and data automation subsystem; (8) power booster regulators and nickel cadmium battery, which supplements primary power source – 17,472 n-on-p solar cells (4,368 per panel) providing nominal 800 watts near Earth, decreasing to 449 watts at Mars distance. Temperature control maintained by combination of thermal louvers, deployable sunshade, aluminized teflon insulation, paint patterns, and polished metal surfaces. Thermal control flux monitor experiment on both spacecraft to provide measurements of the sun's intensity during the trip to Mars and beyond. Attitude control provided by redundant, six-jet nitrogen-gas thrusters with input from three gyros, Canopus star tracker located on upper ring structure of the base, and two primary sun sensors mounted on pedestals atop the base; four secondary sensors attached to lower ring adapter. Data automation subsystem to control and synchronize five scientific experiments, and digitalize data prior to transmission to Earth. Increased bit quantities and rates over Mariner IV include: 3.9 million bits in each TV experiment picture (versus 240,000 bits for Mariner IV); engineering channel bit rates ranging from 8-1/3 to 33 bits per second; science



High resolution image recorded on August 5, 1969 by Mariner VII during near encounter with Mars shows southern polar cap.

channel rates ranging from 66-2/3 bps during encounter to 270 bps during data storage playback, capable of expansion to 16,200 bps on the alternate high rate science channel; and total capacity of tape recorders equivalent to about 195 million bits. S-band receivers on both spacecraft operate at slightly different settings near 2115 mHz. Transmitter operated at about 2195 mHz, also with slightly different settings for each vehicle; contained two sets of redundant exciters, and RF power amplifiers that employed TWT's; was capable of 10 or 30 watt output for feeding either the high-gain or low-gain antennas on each vehicle. Midcourse correction propulsion system on each vehicle for one or two maneuvers in flight provided 51.3 pounds of continuous thrust, could burn for as short as 100 milliseconds; used anhydrous hydrazine propellant and spontaneous catalyst for decomposition of hydrazine; rocket nozzle protruded from one of the eight sides of the base below solar panels.

Project Results – Mariner VI: launched February 25, 1969 from Cape Kennedy in a direct ascent single-burn ballistic trajectory with an initial heliocentric injection velocity of 25,700 miles per hour. About 30 minutes after launch, the spacecraft was rotated from random attitude, to acquire the sun. About four hours out, the vehicle was again rotated to lock on Canopus, and space-stabilized with solar panels perpendicular to the sun for the remainder of the flight. A midcourse trajectory correction was made on February 29, while the spacecraft was 750,000 miles out. Mariner VI was ahead of Mars at launch but affected by solar gravity, slowed to 17,633 mph relative to Mars so that Mars passed the spacecraft and slightly ahead of it at encounter. Mariner IV crossed the orbit of Mars within 2120 miles, July 31, 1969, on its equatorial flyby, and subsequently flew behind the planet for about 25 minutes. There were three encounter experiment phases: far-encounter, near-encounter, and occultation and playback. Far-encounter began at encounter minus 54 hours (E-54) and ran to E-7 hours. The far-encounter picture-taking sequence for Mariner VI ranged from E-48 to E-7 hours and was preceded by a period when the scientific instruments, data systems, and telemetry were turned on. The narrow-angle Camera B took 33 full-disk analog pictures of the planet, which were then fed to Earth, followed by a series of 17 pictures recorded from E-22 and E-7 hours. During an 18-minute near-encounter period, 22 pictures from both cameras A and B were taken, for a total of 75 for this flyby. The occultation experiment began about E-11 minutes. The absence of a veiling haze, seen earlier in Mariner IV pictures, corroborated, and countered the theory that the planet had a relatively dense and hazy atmosphere extending to 93 miles.

Mariner VII: launched March 27, 1969 from Cape Kennedy in a direct ascent single-burn ballistic trajectory with an initial heliocentric injection velocity of 25,700 miles per hour. About 30 minutes after launch, the spacecraft was rotated from random attitude, to acquire the sun. About four hours out, the vehicle was again rotated to lock on Canopus, and space-stabilized. A midcourse trajectory correction was made on April 8, while Mariner VII was 2.5 million miles out. Mariner VII was ahead of Mars at launch but, affected by solar gravity, it slowed to 16,063 miles per hour relative to Mars, so that Mars passed the spacecraft and was slightly ahead of it

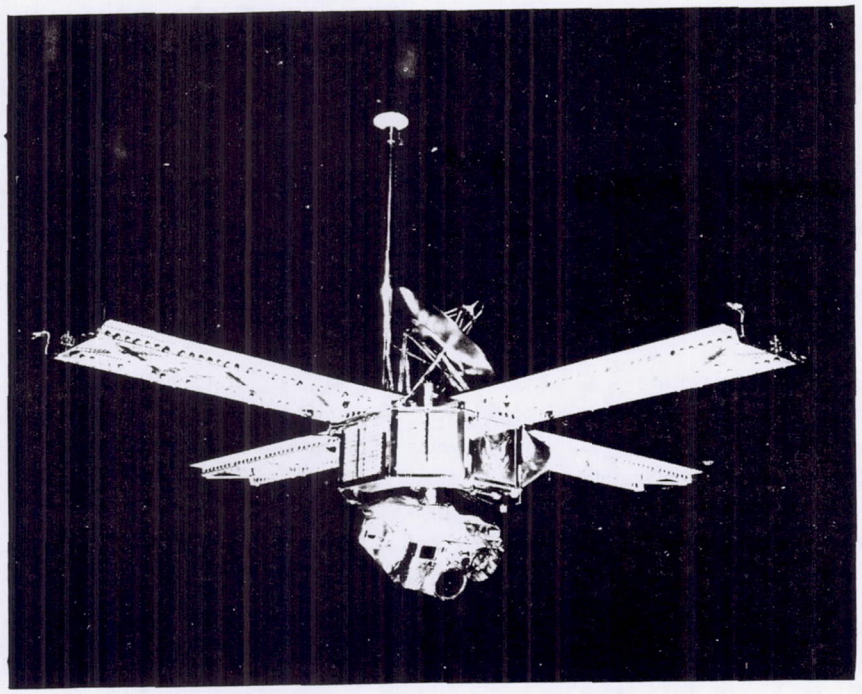
at encounter. Mariner VII crossed the orbit of Mars within 2190 miles, August 5, 1969, on its trajectory over the region from the equator to the South polar cap, and subsequently flew behind the planet for over 20 minutes. There were the same three encounter phases for Mariner VII as for its earlier twin. Far-encounter for Mariner VII began about encounter minus 72 (E-72) hours, and resulted in 93 far-approach analog pictures with Camera B; during near-encounter, 33 pictures were taken with both cameras, for a total of 126 for Mariner VII. Occultation experiment also began at about E-11 minutes.

Joint Flight Results: When the Mars flyby mission phase ended, both spacecraft continued to transmit, their 20 watt outputs being used in continuing celestial mechanics experiments. When they passed behind the sun, tests were made of the theory of electromagnetic radiation bending when in the vicinity of the large solar gravitational fields. Television experiments: transmitted nine times the number of proposed far-encounter TV pictures, 20 percent more near-encounter pictures; a total of 1100 analog and digital pictures. Pictures gave little indication of any atmospheric "cloudiness" except thin aerosol haze, near the bright limb and the polar cap, similar to Earth's tropopause; altitude varies horizontally between 12 to 18 miles; it is layer-like and generally about 5 to 10 miles thick. Three types of terrain were noted: crater, featureless (plains), and chaotic, the latter not found on the Moon, and not comparably found on Earth. Craters ranged from 31 to 200 miles (Nix Olympica). South polar cap measured as several feet thick. IRR experiment: very successful, revealed South polar cap temperature to be between -180°F to -193°F, approximately the range of frozen CO_2 in atmospheric pressure of 6.5 millibars (equivalent to Earth altitude of 100,000 to 125,000 miles). Polar cap edge temperatures plotted within two arc degrees on surface ranged from about -60°F to -190°F. Surface daytime temperatures in other regions measured from -63°F to +62°F; night side readings were -63°F to -153°F. IRS experiment: With Mariner VII, some 250 spectral readings were taken, one every 10 seconds, including sweeps over Meridianii Sinus and Hellespontus regions. Confirmed temperature reading from IRR. Detected virtual 90 percent solid and gaseous carbon dioxide saturation of Martian atmosphere at high altitudes, and on surface; revealed thin, extremely slight content waterized atmospheric "fog" at all latitudes; refuted earlier theory of possible existence of methane or ammonia content in atmosphere near south polar cap; and detected presence of silicate material solids. UV Spectrometer: also very successful, confirmed presence of CO_2 at 81 miles above surface. Also detected ionized CO_2, carbon monoxide, atomic hydrogen, and very slight traces of molecular oxygen; no nitrogen or nitric oxide were detected. S-band occultation: both spacecraft tests successful. Indicated possible 90 percent CO_2 saturation of atmosphere; revealed atmospheric pressure averaged between 6 to 7 millibars, ranging from 5 to 9 millibars, temperatures averaged -90°F. Ionospheric electron density at 25 miles measured at 1.5×10^5 electrons per cubic centimeter. Corroborated possibility of presence at 15, 31, and 37 miles of solid CO_2. Confirmed previous dynamic estimates of the oblateness of Mars.

Major Participants – Jet Propulsion Laboratory, Mariner VI and VII project management, spacecraft prime contractor, Deep Space Network operations and experimenter; Philco-Ford, radio communication subsystem; Motorola, Command subsystem, central computer and sequencer; Texas Instruments, telemetry and data storage subsystems; Litton, data automation subsystem; Xerox Electro-Optical Systems, Honeywell, and Northrop, electronics and engineering mechanics packages; TRW, midcourse correction propulsion subsystem and temperature control flux monitor; Universities of California and Colorado, California Institute of Technology, JPL, experimenters; NASA Lewis Research Center, launch vehicle management; General Dynamics, prime contractor.

Key Spacecraft Personnel		Affiliation
Mariner VI		
PM	H. M. Schurmeier	NASA-JPL
CO	N. W. Cunningham	NASA Headquarters
CO	R. F. Fellows	NASA Headquarters
CO	R. Kennedy	NASA Headquarters
Mariner VII		
PM	H. M. Schurmeier	NASA-JPL
CO	N. W. Cunningham	NASA Headquarters
CO	R. F. Fellows	NASA Headquarters
CO	R. Kennedy	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Mariner VI			
Mars Surface TV Camera	PI	R. B. Leighton	California Institute of Technology
Iridium Spectrum 1.5-15 Micron	PI	G. C. Pimentel	University of California, Berkeley
	OI	K. C. Herr	University of California, Berkeley
Iridium Radiometer	PI	G. Neugebauer	California Institute of Technology
	OI	G. Munch	California Institute of Technology
	OI	S. C. Chase, Jr.	Santa Barbara Research Center
Ultraviolet Spectrometer Experiment	PI	C. A. Barth	University of Colorado
	OI	C. W. Hord	University of Colorado
	OI	J. B. Pearce	Science Applications, Inc.



Twin Mariners VI and VII, launched one month apart, were to arrive at Mars only five days apart, after months-long voyages to the red planet. The Mariners weigh 910 pounds and with solar panels spread have wingspans of 19 feet.

Experiment	Experiment Personnel	Affiliation
Celestial Mechanics	PI J. D. Anderson	NASA-JPL
S-Band Occultation	PI A. J. Kliore	NASA-JPL
Radiometer, Solar Const.	PI J. A. Plamondon	NASA-JPL
General Relativity	PI J. D. Anderson	NASA-JPL
Mariner VII		
Mars Surface TV Camera	PI R. B. Leighton	California Institute of Technology
Iridium Spectrum 1.5-15 Micron	PI G. C. Pimentel	University of California, Berkeley
	OI K. C. Herr	University of California, Berkeley
2 Channel Iridium Radiometer	PI G. Neugebauer	California Institute of Technology
	OI G. Munch	California Institute of Technology
	OI S. C. Chase, Jr.	Santa Barbara Research Center
Ultraviolet Spectrometer Experiment	PI C. A. Barth	University of Colorado
	OI C. W. Hord	University of Colorado
	OI J. B. Pearce	Science Applications, Inc.
Celestial Mechanics	PI J. D. Anderson	NASA-JPL
S-Band Occultation	PI A. J. Kliore	NASA-JPL
Radiometer, Solar Const.	PI J. A. Plamondon	NASA-JPL
General Relativity	PI J. D. Anderson	NASA-JPL

ESSA IX

Launch Vehicle – Thrust Augmented Improved Delta (TAID): Thor first stage with three Castor II strap-on solid-propellant motors with a total thrust of 370,000 pounds; 7700-pound-thrust second stage; and 6200-pound-thrust FW-4 solid-propellant third stage. First and second stages radio guided, third stage spin stabilized. Height 92 feet.

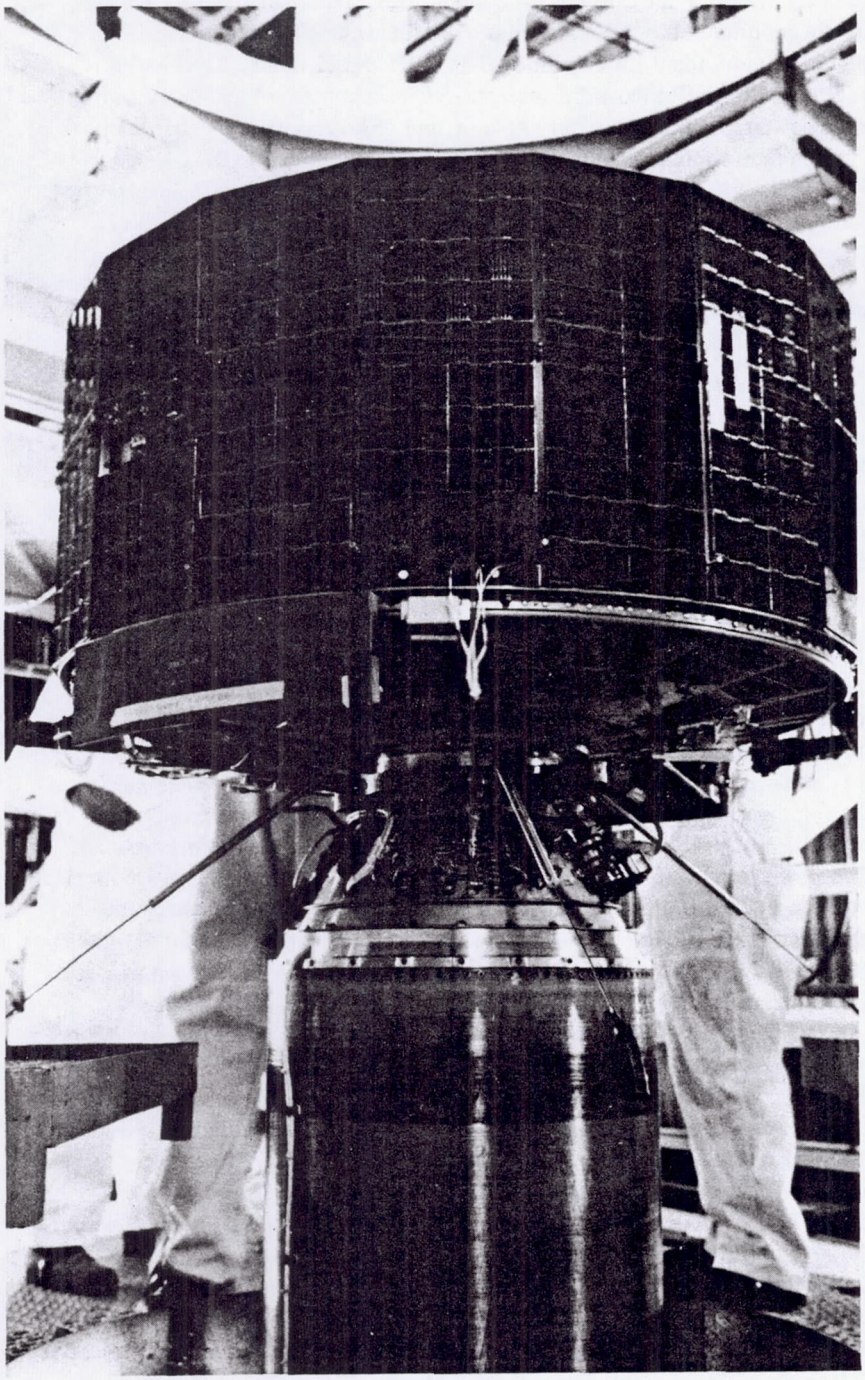
Spacecraft Description – Standard Tiros-ESSA configuration: hatbox-shaped 18-sided polygon, 22 inches high and 42 inches in diameter. Covered by 10,020 n-on-p solar cells. Single 18-inch receiving antennas projected from top, four 22-inch transmitting antennas extended from bottom. Two 1-inch Advanced Vidicon Camera System (AVCS) cameras mounted 180° apart on side of spacecraft. Spin stabilized at 9.2 rpm. Weight 320 pounds.

Project Objectives – Ninth Environmental Survey Satellite in the Tiros Operational Satellite (TOS) system. Standby and replacement for ESSA VII, to serve as the primary stored-data satellite in the TOS system, because of failure of one of the two AVCS cameras on ESSA VII, and to ensure full operational capability of the TOS system in the event of any additional failures in ESSA VII. The full complement of Tiros Operational Satellites provided global pictures to aid in weather forecasting and warning. Picture readout occurred at ESSA's Command and Data Acquisition Centers at Fairbanks, Alaska and Wallops Island, Virginia for transmission to ESSA's National Environmental Satellite Center where digital mosaics were projected on maps, and distributed internationally from the World Meteorological Center in Washington by radio-facsimile and direct circuit, terminating at the World Meteorological Center in Moscow.

Spacecraft Payload – Two one-inch AVCS cameras, programmed to take 800-line pictures every 260 seconds while satellite is in daylight. From 865-mile altitude, resolution was about two miles per scan line at picture center, with each picture covering an area of about 2000 miles on a side. Each picture was retained by the layer on face of vidicon tube for about seven seconds while being converted to signals for storage on magnetic tape recorder. Two cross-connected tape recorders, each capable of storing 48 frames for later transmission. Two arrays of radiometer sensors mounted 180° apart measure global distribution of solar radiation reflected by Earth and Earth's atmosphere, as well as long-wave radiant energy emitted by Earth. Power from solar cells stored in 63 nickel-cadmium batteries.

Project Results – ESSA IX was launched February 26, 1969 from Cape Kennedy into a sun-synchronous near polar orbit ranging from 883 to 943 miles at an inclination of 102°. TOS system has provided worldwide and local cloud-cover pictures daily since the launch of ESSA I in February 1966. Local readout was possible from APT-camera-bearing satellites (ESSA II, VI, & VIII). Up to January 15, 1969, before the launch of ESSA IX, the four previous AVCS satellites had transmitted 275,174 useable pictures and been instrumental in preparing 3979 storm advisories.

Major Participants – ESSA, project management; NASA Goddard Space Flight Center, spacecraft and launch vehicle management; RCA, spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.

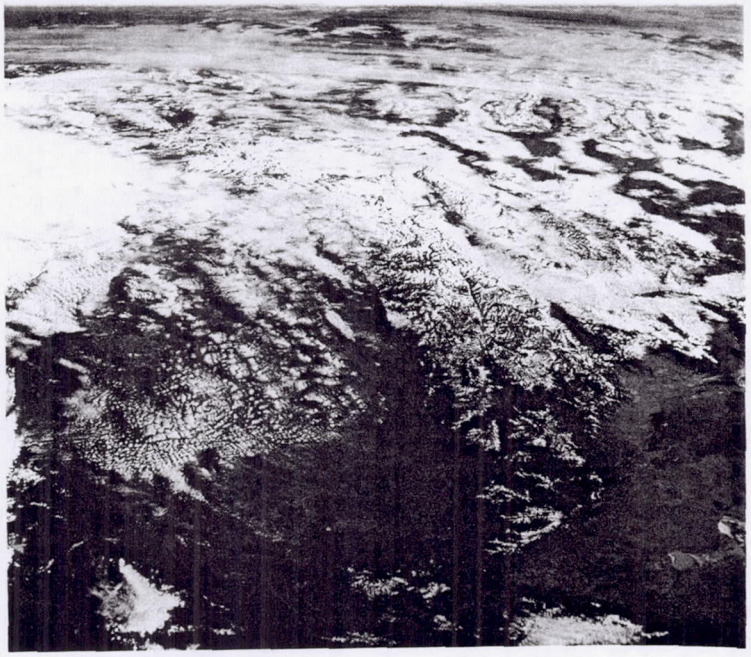


ESSA IX (TOS-G) was the ninth and last in the series of TOS weather satellites.

APOLLO IX

Launch Vehicle – Saturn V (SA-504), S-IC first stage, containing five F-1 engines producing total thrust of 7.7 million pounds. S-II second stage, containing five J-2 engines yielding up-rated thrust of 1.15 million pounds. S-IVB third stage, containing one J-2 engine generating 232,000 pounds of thrust at first burn, 211,000 pounds of thrust at second burn after separation from docked CSM-LM configuration, for injection of the S-IVB into solar orbit. Instrument Unit (IU), a cylinder three feet high and 21.7 feet in diameter mounted atop the third stage, contained the guidance, navigation, and control equipment for combined S-IVB-CSM-LM vehicle Earth-orbit flight, and for S-IVB solar orbit insertion; IU also contained telemetry, communication, tracking, crew-safety system, and self-supportive electrical and environmental-control equipment. S-IC height 138 feet, S-II 81.5 feet, S-IVB 58.3 feet. Total height including Launch Escape System atop spacecraft section, 363 feet.

Spacecraft Description – Total spacecraft configuration consisted of Command Module (CM) 104 and Service Module (SM) 104 (known together as "Gumdrop"), Lunar Module (LM) 3 ("Spider"), Spacecraft-Lunar Module Adapter (SLA) 12, and a Launch Escape System (LES) atop the CM. LES: comprised an open frame tower structure with three solid-propellant motors, a 147,000-pound-thrust main motor mounted atop the tower; a 31,500-pound-thrust tower jettison motor; and a 2400-pound-thrust pitch control motor for bending the CM's escape trajectory away from the launch vehicle and/or pad area, in case of abort. Two deployable canard vanes located atop the LES tower element to function aerodynamically to turn the CM to a heat-shield-forward position. Boost protective cover, composed of glass, cloth, and honeycomb, attached to base of LES to protect CM from rocket exhaust gases.. Height of total LES, 33 feet; weight 8848 pounds. CM structure: a conical pressure vessel 12 feet high and 12 feet 10 inches in base diameter, encased in heatshields and consisting of three compartments. Forward compartment contained two negative-pitch reaction control engines and components of Earth landing system; crew compartment, with 210 cubic feet of habitable volume, contained crew accommodations, controls and displays, and spacecraft systems. Aft compartment housed 10 reaction control engines and propellant tanks. Heat shields made of brazed stainless steel honeycomb filled with phenolic epoxy resin as ablative material, with thickness ranging from 0.7 to 2.7 inches, according to anticipated heat loads. CM inner structure made of aluminum honeycomb sandwich, bonded between sheet aluminum alloy, ranging in thickness from 0.25 inches at forward access tunnel to 1.5 inches at base. Mounted in CM forward tunnel was the probe assembly: a folding, coupling, and impact-attenuation device that mated with a conical drogue mounted on the LM docking tunnel. Probe and drogue assemblies both removable for stowing to allow free access to tunnels for crew transfers while CM and LM are docked. Weight 12,405 pounds. SM structure: a cylinder 12 feet 10 inches in diameter and 22 feet high, with outer skin formed of inch-thick aluminum honeycomb panels, and interior divided into six sections by milled aluminum radial beams. The six sections contained fuel cells and on-board consumables, and fuel and oxidizer tankage for service propulsion system and reaction control system (RCS) engines. Weight 36,159 pounds. LSA: 28-foot-high truncated cone

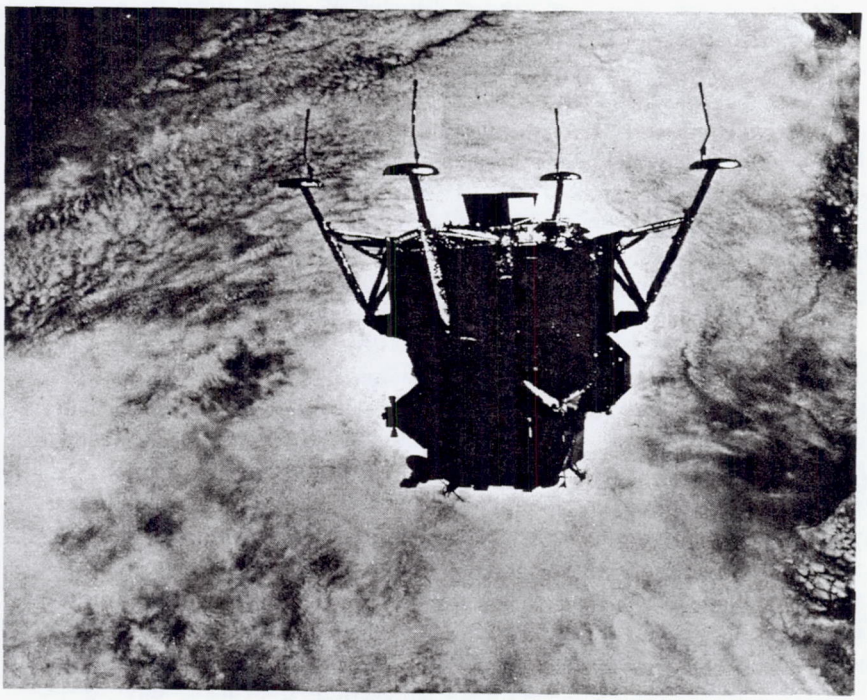


The Sierra Nevada, San Joaquin Valley and the Mojave Desert as photographed by the Apollo IX astronauts.

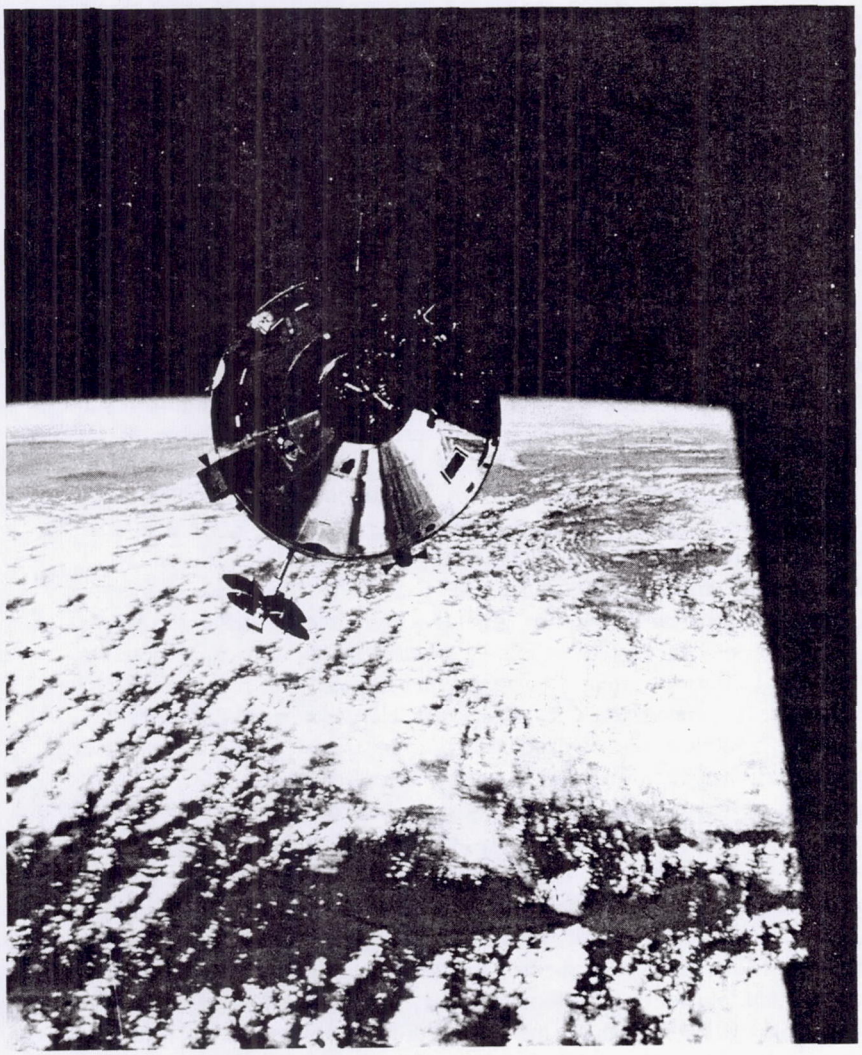
tapering from 260 inches in diameter at base to 154 inches at forward end, where it mated with SM, with four jettisonable wall panes of 1.75-inch-thick aluminum honeycomb. On Apollo IX, SLA served as a shroud for the LM and as the structural interstage between IU and SM. Weight 4107 pounds. LM structure: an aluminum/aluminum-alloy two-stage vehicle designed for space operations only (did not have re-entry capability), 22 feet 11 inches high, consisting of separable lunar ascent and descent stages that function as a unit until mission staging events, following which the ascent stage acts as a single vehicle for rendezvous and docking with the CSM either for Earth-orbital test mission or lunar landing flights. Descent stage was an unpressurized, load-bearing, octagonal structure 10 feet 7 inches high with a main compartment 14 feet 1 inch diagonally, which increased to 31 feet after extension of folded landing gear struts made of crushable aluminum honeycomb with footpads 37 inches in diameter, beneath which extend surface-sensing probes that signal for descent engine shutdown on contact. Descent stage center compartment housed the descent engine (DE), was surrounded by four square equipment bays that housed DE propellant tanks and – on lunar landings – scientific experiment payloads. Intermediate triangular bays contained environmental control system (ESC) water tanks, helium and gaseous oxygen tanks, and DE control assembly of the LM primary guidance and navigation system (PGNS). Structure was encased in mylar-aluminum alloy thermal and micrometeoroid shield. External platform ("porch"-like), was mounted on the forward outrigger below the forward hatch. Ladder, for crew egress and ingress during lunar surface operations, extended down from forward landing gear strut. Weight of descent stage without propellants was 4265 pounds; with propellants, 22,209 pounds. Ascent stage, 12 feet 4 inches high, 14 feet 1 inch diagonally, consisted of three main sections: pressurized crew compartment and midsection, and unpressurized equipment bay, aft. Three other substructural areas contained ascent thrust chamber assembly, cluster supports, and antenna supports. Cylindrical crew compartment, 235 cubic feet in volume, was a ring-stiffened semi-monocoque structure 92 inches in diameter and 42 inches high, containing control and display panels, body and arm rests, landing aids, two triangular front windows, a 32-inch-square inward-opening forward hatch, an overhead docking window,

and an alignment optical telescope. Ascent stage midsection contained the LM guidance computer, power and servo assembly, ascent engine propellant tanks, reaction control system and RCS propellant tanks, ECS, and waste management section. A tunnel ring, atop the ascent stage, meshed with the CM latch assemblies and was aligned during docking by the LM drogue and the CSM probe. Docking and crew transfer tunnel extended 16 inches downward into the midsection, was 32 inches in diameter, with upper hatch on inboard end of tunnel hinged downward and unopenable when LM is pressurized. Ascent stage also encased in mylar-aluminum alloy thermal and micrometeoroid shield. Weight of ascent stage "dry" was 5071 pounds; with propellants, 9812 pounds.

Project Objectives – Primary objective of Apollo IX was an Earth-orbital engineering test of a manned lunar module – the first manned LM flight. Concurrent prime objectives included an overall checkout of launch vehicle and spacecraft systems, crew, and procedures, by performing an integrated series of flight tasks in Earth orbit with the CM, SM, joined CSM, LM, and S-IVB stage, both while these modules were linked in launch or various docked configurations, and while they were flying separate orbital patterns. LM tests included functioning independent of the CSM as a self-sufficient spacecraft, and performing active rendezvous and docking maneuvers paralleling those to be performed by the following Apollo X in a lunar-orbit mission. Flight plan's top mission priorities were the CSM and LM rendezvous and docking, performed twice – once while LM was still attached to the S-IVB and again when the LM was active. Further goals were internal crew transfer from the docked CSM to the LM; special tests of the LM's spacecraft supportive systems, crew procedures and mission-control flight equipment, and



The Apollo IX Lunar Module, "Spider," as viewed from the Command Module. Inside Spider were astronauts James A. McDivitt and Russell L. Schweickart.



The Earth-orbital Apollo IX rendezvouses prior to docking. This was the first manned flight to test the lunar landing hardware.

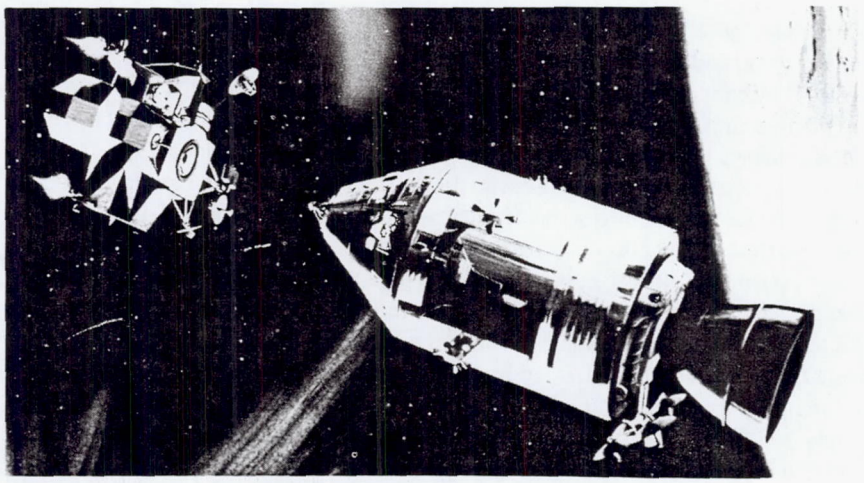
LM pilot's EVA mobility unit (EMU); and configuring of the LM to support a two-hour EVA, simulating LM crew rescue and the only planned EVA from the LM before actual lunar landing. LM descent and ascent engines were to be fired on orbital change patterns to simulate both a lunar-orbit rendezvous and backup abort procedures. The CSM Service Propulsion System (SPS) was to be fired five times, including a simulation of an active rendezvous to rescue an LM which has become inactivated. After separation of the CSM from the SLA in Earth orbit, followed by jettisoning of the SLA's LM protective panels, the CSM was to transpose position and dock with the exposed LM; the docked modules then were to be separated, and the spacecraft was to adjust its orbit 2000 feet away from the S-IVB stage. The S-IVB engine then was to be restarted twice, the second firing to place the stage in an Earth-escape trajectory and into solar orbit, simulating trans-lunar-injection ability of the stage for Apollo X and subsequent lunar missions. Other objectives included the multispectral photographic experiment, as tests for subsequent unmanned Earth resources spacecraft.

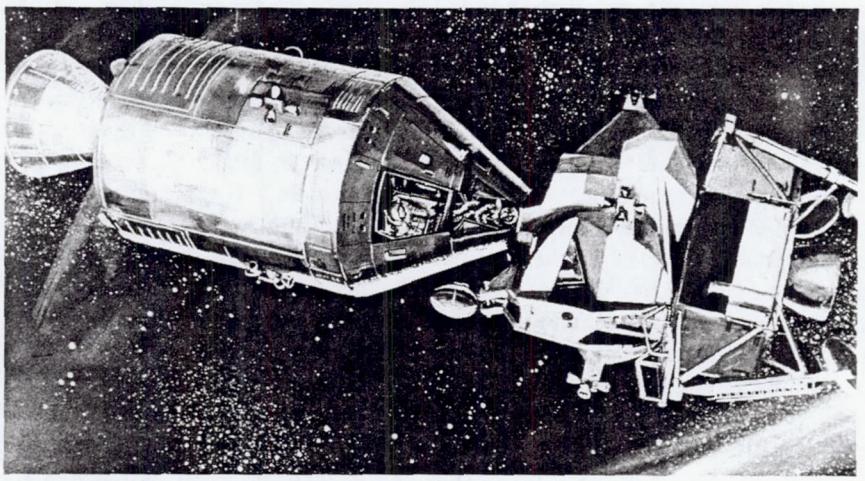
Spacecraft Payload – Spacecraft Commander James A. McDivitt, Command Module Pilot David R. Scott, and Lunar Module Pilot Russell Schweickart. McDivitt, a USAF Colonel, was 40; Scott, also a USAF Colonel, was 37; and Schweickart, a civilian, was 34. Command and Service Modules (CSM) spacecraft contained necessary mission and life-support systems and experiment equipment. Inertial and computer-based guidance and navigation system controlled position, attitude, velocity, propulsion and thrust vectors, calculated trajectories, and displayed abort data; had optical equipment for celestial and landmark navigation. Stabilization and control system controlled rotation and translation; backed up guidance system. Gimbal-mounted SPS provided 20,500 pounds of constant thrust from re-startable hypergolic-liquid propelled engine for large velocity changes of the CSM, controlled either automatically or manually. Reaction control systems (RCS) for CM and SM were independent, CM RCS consisting of two redundant subsystems each comprising six 94-pound-thrust liquid-propelled engines. Both CM RCS were activated after CM-SM separation, one being used for CM attitude control during Earth re-entry, the other for backup. SM, RCS comprised four identical clusters mounted 90° apart near top of SM, and consisting of four 100-pound-thrust liquid-propelled engines providing redundant spacecraft attitude control, and used for small velocity change maneuvers. Electrical power was generated by three 31-cell hydrogen-oxygen fuel cells in the SM, supplying 28-volt-DC power. Spacecraft environment control system regulated cabin atmosphere, pressure, and temperature, plus regulating CO_2, odors, particles, and ventilation of the cabin after landing; also controlled electronic equipment temperatures. Telecommunication system included voice, television, data, and tracking and ranging subsystems, for intercommunication between astronauts and for Earth-spacecraft and spacecraft-LM links. Other equipment included PCM telemetry for communication with the Manned Space Flight Network ground stations; VHF/AM voice subsystems and unified S-band tracking transponder; and VHF recovery beacon. High-gain steerable S-band antenna consisted of four 31-inch-diameter parabolic dishes on a folding boom at aft end of SM, plus omnidirectional antenna. Controls and displays were housed in the CM crew compartment, were grouped by system and frequency-of-use patterns, and designed for operation by crewmen wearing pressurized suits. Earth landing system in CM included two reefed 16.5-foot-diameter drogue parachutes, and pilot mortar chutes to pull out three main 83.3-foot-diameter parachutes. Other CM recovery aids included inflatable up-righting system to maintain proper CM attitude in the sea, interphone connections for recovery swimmers, fluorescent sea-dye marker, flashing beacon, VHF transceiver. LM spacecraft systems: were independent of CM, providing for separate flight of vehicle. Electrical power was supplied by six primary batteries – four in the descent stage – providing 28 volts. Environmental control system provided atmosphere revitalization, cabin-pressure control, water management, heat control, and oxygen and water servicing of the crew's Portable Life Support System (PLSS) spacesuit backpacks. The 367 pounds of water on board the LM was contained in three nitrogen-pressurized bladder-type tanks in the descent stage and two 47.5-pound tanks in the ascent stage. Communication system comprised two S-band transceivers, two VHF transceivers, a UHF command receiver, signal-processing assembly,

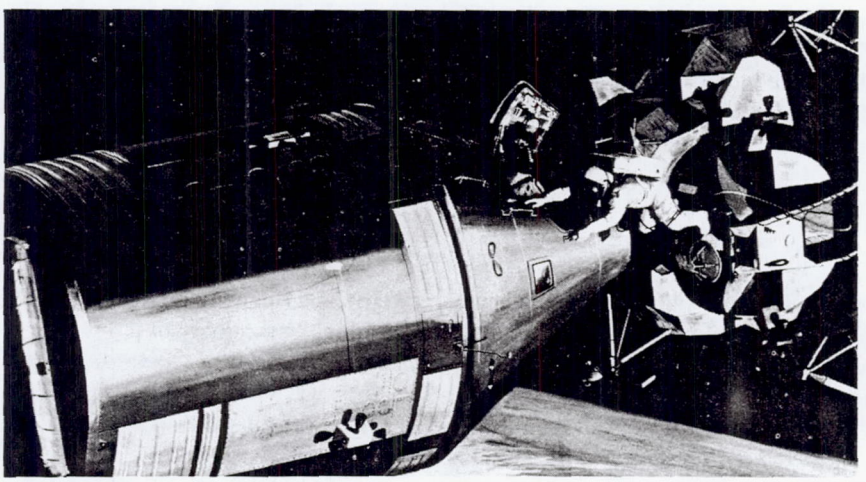
data storage assembly comprising a four-channel voice recorder with 10-hour capacity, and one 26-inch-diameter paraboloid S-band inflight antenna, two VHF inflight dishes, four C-band backup antennas for tracking, and two UHF/VHF scimitar antennas for relaying developmental flight instrumentation telemetry. LM guidance, navigation, and control system had six elements: primary guidance and navigation system (PGNS), abort guidance system (AGS), radar, control electronics section (CES), and orbital-rate drive electronics. Reaction control system (RCS) consisted of four clusters of four 100-pound-thrust hypergolic-liquid-fueled engines, comprising two redundant parallel systems; additionally, interconnect valves permitted the RCS to draw from ascent engine propellant supplies if needed. LM descent engine (LMDE) was a pressure-fed hypergolic-liquid bipropellant engine, producing a maximum 9850 pounds of thrust, throttleable down to approximately 1050 pounds of thrust; could be gimballed six degrees in any direction for offset center-of-gravity trimming. Ascent stage propulsion system was not gimballed, performed at full 3500 pounds of thrust. Tracking and docking lights were mounted on the LM: one light, mounted on the front face, flashing once per second and visible 150 miles to the eye (461 miles through the CSM sextant), was a contingency aid for active CSM-LM rendezvous and rescue; five docking lights analogous to aircraft running lights included two forward yellow lights, an aft white light, portside red and starboard green lights, with 1000-foot visibility. Other CSM payload and experiment equipment were general- and special-design still, sequence, and television cameras. Replacing the camera used on Apollo VIII was a specially designed TV camera, flown for the first time on Apollo IX as a test for later use on Apollo XI, which weighed 7.25 pounds and had a light-sensitivity range from 12,600 foot-lamberts down to 0.007 foot-lamberts. Imaging tube was a secondary-electron-conduction tube operating with 320 scan lines at 10 frames per second, with alternate high-resolution mode at 1280 lines at 0.625 frames per second. Two fixed-focus lenses included a wide angle, for use inside the CSM, and a general-purpose lunar day lens, incorporating a filter. The SO-65 multispectral terrain photography experiment equipment included four 500-EL Hasselblad cameras electrically driven, in a ring mount and synchronized for simultaneous exposures, installed in the CM hatch window during experiment operations when spacecraft was oriented to provide vertical photography. Each camera equipped with a standard 80-millimeter focal-length lens. For general-purpose photography, Apollo IX carried two 70-millimeter Hasselblads, each with an 80-millimeter and a 38-millimeter superwide angle lens, and two 16-millimeter Mauer sequence cameras with interchangeable 75, 18, and 5 millimeter focal-length lenses.

Project Results – Apollo IX was launched from Cape Kennedy on March 3, 1969 into a nominal 117-by-119-mile Earth orbit. In summary: all prime mission objectives were met; all major spacecraft systems were successfully demonstrated; the few off-nominal conditions that developed did not affect achievement of major goals. On the first day, after orbit injection of the combined S-IVB stage and its SLA-LM-CSM payload, venting of the S-IVB

An artist's concept of critical Apollo IX objectives: (1) rendezvous, (2) docking and (3) extra vehicular activities (EVA). The EVA performed by astronaut Russell L. Schweickart lasted 67 minutes.







propellant tanks changed the orbit to 123 by 127 miles. The CSM was separated and the SLA panel walls were jettisoned, following which the CSM transposed 180° and maneuvered toward the LM atop the S-IVB, and docked with the LM in the second orbit. The linked modules were ejected from the S-IVB, the thrust placing the CSM-LM a safe distance away for a 62-second restart of the S-IVB that raised its apogee to 1895 miles. A second restart of four minutes two seconds, to effect a hyperbolic orbit for the planned escape trajectory of the S-IVB, was off nominal and resulted in about 11 percent less than the desired maximum velocity increase; while this did not affect the Apollo IX flight, a lunar mission might have been aborted. Before this third S-IVB burn, the CSM Service Propulsion System (SPS) was fired for five seconds and placed the CSM in an orbit of 125 by 145 miles. The firing was to improve orbital lifetime, check the capability of the guidance and navigation system to control the burn, and perform a hard check of the LM's ability to withstand thrust acceleration and vibration. The second SPS firing for one minute five seconds occurred on March 4th; it changed Apollo IX's orbit to 123 by 213 miles; tested the structural dynamics of the docked CSM-LM under loads approximating those of a lunar mission. A third SPS firing the same day, for four minutes 42 seconds, changed the orbit to 126 by 313 miles, while the fourth burn, lasting for 28.2 seconds was an out-of-plane change. On March 5, the third day of flight, McDivitt and Schweickart put on space suits and transferred to the LM through the tunnel connection and performed a systems checkout of the LM. This included a 367-second firing of the LM descent engine to simulate the throttleable pattern to be used during a lunar landing mission. McDivitt controlled the final 59 seconds, varying the thrust from 10 to 40 percent and shutting it off manually; this was the first manned throttling of an engine in space, and increased the spacecraft's orbit to 130 by 300 miles. After nine hours, the crewmen transferred from the LM to rejoin Scott in the CSM, which was followed by the fifth firing of the SPS, the final shaping maneuver prior to the rendezvous exercises to be performed two days later; the firing placed Apollo IX into an orbit of 142 by 149 miles. On Day 4, McDivitt and Schweickart again entered the LM. Because of nausea, Schweickart's scheduled two-hour EVA to simulate external transfer rescue techniques was cancelled and, instead, he climbed out on the LM porch for a 37.5-minute EVA, to conduct a test of the astronauts' extravehicular mobility unit (EMU), including the portable life support system (PLSS) back pack. On March 7, the fifth day, with McDivitt and Schweickart again on board the LM, it was separated from Scott's CSM. The LM descent engine was fired once for 24.9 seconds to place the craft into a 137-by-167-mile orbit, and then again for 24.4 seconds, controlled by the LM PGNS, to circularize the orbit about 154 by 160 miles, some 12 miles higher than the CSM. Four hours later, horizontally 113 miles away from the CSM, the LM descent stage was jettisoned for a first-time firing in space of the ascent stage engine. It lowered the LM orbit by 11 miles, and placed it 75 miles behind and 10 miles below the CSM, to commence rendezvous in a simulation of a lunar landing mission. Six hours later the CSM and LM were redocked. The LM ascent stage was jettisoned and commanded to fire its engine to fuel depletion. On the sixth day a sixth firing of the CSM SPS, although postponed one revolution, lowered the orbit to 121 by 138 miles. On the seventh day the crew per-

formed Earth landmark tracking over the U.S. and the South Atlantic. On March 10, the eighth day, a seventh burn of the SPS altered the orbit of Apollo IX again, to 113 by 288 miles. No major mission activities were scheduled for the ninth day. Two telecasts were made to Earth from Apollo IX. The first, on March 5, lasted for almost seven minutes. The second telecast on the following day lasted about 13 minutes and, like the first, only showed interior views of the LM. Photographs taken as part of the multispectral terrain photographic experiment were successful. On March 13, (10th day), after re-entry was extended one revolution because of heavy seas in the primary recovery area, Apollo IX, 600 miles into its 152nd revolution, splashed down at 23.25°N. and 68°W., about 341 miles north of Puerto Rico and within three miles and in full view of the recovery ship. The flight consumed 241 hours 53 seconds; 10 seconds longer than planned. The S-IVB stage was in heliocentric orbit; the LM ascent stage was in Earth orbit; and the LM descent stage decayed on March 22, 1969.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell, CM and SM spacecraft prime contractor; SPS, Aerojet-General, principal and subcontractors; AVCO, ablative heat shield; Collins, communication and data subsystems; Garrett, environmental control system; Grumman, LM spacecraft prime contractor; PGNS, General Motors (manufacturing), MIT (technical management), principal and subcontractors; NR, ascent engine; RCA, communication subsystem and radar and control electronics; TRW, descent engine and abort guidance system; IBM, IU prime contractor; Boeing, Apollo/Saturn V technical integration and evaluation; GE, Apollo checkout equipment, related engineering design, quality management, and engineering support; TRW, mission trajectory control and spacecraft system analysis; NASA Marshall Space Flight Center, launch vehicle management; Boeing, first stage prime contractor; NR, second stage; McDonnell Douglas, third stage; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, Manned Space Flight Network management.

Key Spacecraft Personnel		Affiliation
MG	G. E. Mueller	NASA Headquarters
PM	W. C. Schneider	NASA Headquarters
PM	C. W. Mathews	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Spectral Terrain Photos	PI	R. J. Allenby, Jr.	NASA Headquarters

NIMBUS III (SECOR 13)

Launch Vehicle – Thorad-Agena D (uprated version of the Thrust-Augmented Thor, used in conjunction with an Agena second stage, has greater tank volume than previous vehicles): 170,000-pound-thrust Thor first stage augmented by three strap-on solid rocket motors providing 52,130 pounds of thrust; Agena D second stage at 16,000 pounds of thrust. Height 109.5 feet.

Spacecraft Description – Nimbus III was composed of three major elements: a 5-foot-diameter sensory section, a hexagonal upper section, and two 8-by-3-foot rotating solar panels. Upper and lower sections are connected by a truss structure. Sensory ring, a hollow circular section, contained all the weather-measuring experiments as well as spacecraft batteries, transmitters, and associated electronic equipment. Stabilization and attitude control subsystem, housed in upper section, was Earth oriented and stabilized within one degree on three axes. Spacecraft was 10 feet high, 11 feet across the solar panels. Weight: a heavyweight record for meteorological satellites, 1269 pounds. Secor 13: rectangular package 9 by 11 by 13 inches, covered by solar cells. Eight antennas extended from sides, one from top. Weight 45 pounds.

Project Objectives – Nimbus III was a replacement for Nimbus B, destroyed in a launch failure in May 1968 at WTR. Nimbus III was to be first U.S. weather satellite to make night and day global measurements from space of temperatures of the atmosphere, both over extended periods and, for the first time, at varying levels vertically. Obtaining such meteorological data, principally from over large bodies of water and marginally habitable land masses, and on such a scale, was to make possible experimental computer-derived weather predictions, using mathematical models based on the statistical validity of the scope of the numerical data Nimbus III would return. While meteorological objectives were primary, this mission also was to gather vital oceanographic data for scientific purposes other than solely for weather-casting. Another mission objective was to provide data for the first experiment of the U.S.A. portion of the Global Atmospheric Research Program (GARP), which was an international program of formulating and coordinating research for achieving long-range global weather forecasting. The first experiment, the BOMEX (Barbados Oceanographic and Meteorological Experiment) conducted by seven U.S. governmental agencies in cooperation with the government of Barbados, was to be a study of the joint behavior and interactions of the atmosphere-ocean system in subtropical and tropical waters. Other flight objectives same as for earlier Nimbus B: study of spatial and temporal distribution of atmospheric structure – particularly temperature – and determination of temporal variations in solar radiation (near ultraviolet). Engineering objectives included demonstration of full spacecraft capability for handling multiple experiments, radioisotope power for space use, data collection and ranging system, air-bearing gyro, and solid-state S-band transmitter. Ultimate objective was to demonstrate experiments and techniques for achieving reliable, long-range weather forecasting. Secor 13 (Sequential Collation of Range): continued geodetic position-determination measurements, concentrating on completing accurate measures of distances and locations of islands in the Pacific begun with previous

Secors. Object of this launch was to complete the combined spacecraft and ground station network.

Spacecraft Payload – The seven experiments on Nimbus III, which were identical to those on the aborted Nimbus B observatory, comprised a record for U.S. weather satellites. In addition, however, Nimbus III contained an experimental two-unit nuclear isotopic system for generating electrical power, SNAP 19. (These generators were the same pair that were on board the aborted Nimbus B and were recovered intact and undamaged from the Pacific Ocean, near Vandenberg AFB, where the satellite and launch vehicle had crashed.) Each experiment was a first for the Nimbus program: the IRIS, SIRS, IRLS, MUSE, IDC, HRIR, MRIR, and SNAP-19, which are described in that order. Infrared Interferometer Spectrometer (IRIS) was to be the first meteorological experiment to provide global measurements of temperatures vertically through the depth of the atmosphere, the water vapor content, and ozone distribution. Utilizing a Michelson interferometer with a 100-mile-diameter field of view, and operating in the 6- to 20-micron region, IRIS was to analyze the infrared spectrum radiated from discrete areas of the Earth's surface, or cloud tops, along the orbital path. During each 11-second viewing interval, image motion was to compensate for spacecraft travel. Computer was to compare spectra with the ideal black body curves conforming to Planck's radiation formula. IRIS was also to measure air pollution dispersion of nitrous oxide, methane, and carbon dioxide. Weight: 35 pounds. Satellite Infrared Spectrometer (SIRS) was to take similar readings to those of IRIS but would not measure water vapor or ozone distribution. Utilizing a Fastee-Ebert grating spectrometer that would measure atmospheric energy in the 15-micron band, SIRS was to measure vertical temperature profile of Earth's atmosphere over an area 120 miles square, directly beneath spacecraft. Weight: 91 pounds. The Interrogation, Recording, and Location System (IRLS) was to locate and identify transmissions from remote terrestrial sensors (weather stations, buoys, drifting balloons, Earth strain gauges, and other data platforms), receive and record the data, then relay the results to a ground station for dissemination. Though limited initially to deployment of 12 platforms, IRLS was capable of expansion ultimately to large numbers of permanent or transportable surface or airborne units deployed anywhere in the world. The IRLS could also be applied to oceanography studies, meteorological data sensing, geological surveys (measuring strains in the Earth's crust), hydrology, and ecology. For example, a unique experiment was to use IRLS to monitor and precisely locate a seven-pound ground station platform mounted on an elk in Yellowstone National Park, Wyoming. Weight: 26 pounds. Monitor of Ultraviolet Solar Energy (MUSE) was to measure solar flux in five broad spectral bands to detect variations of intensity. Ultraviolet radiation is related to formation of ionosphere, establishment of ozone layer, and heating of upper regions of stratosphere. Weight: 9 pounds. Image Dissector Camera (IDC) was to take daily television pictures of the entire Earth, each 800-line picture covering about 840,000 square miles and having a resolution of about two miles at picture center, with a total scan time of 200 seconds. Pictures were to be relayed to Automatic Picture Transmission (APT) stations for playback to Goddard Space Flight Center. IDC replaced both the advanced

vidicon camera system (AVCS) and APT packages carried on earlier missions. Weight: 14 pounds. High Resolution Infrared Radiometer (HRIR) and Medium Resolution Infrared Radiometer (MRIR) were both similar to their counterparts on Nimbus II. Operating at 3.4 to 4.2 microns in the infrared spectrum, HRIR was to utilize a lead selenide photoelectric cell to take Earth and cloud cover pictures, with a 5-mile resolution at picture center, over about a 1500-mile-wide strip on the night side of each orbit. Modification was made from Nimbus II version to allow HRIR to provide useful daytime pictures as well. Weight: 18 pounds. Objectives of MRIR were to determine effect on weather of Earth's radiation balance and to map atmospheric motion and jet streams. Consisted of a five-channel radiometer designed to measure albedo radiation as well as atmospheric temperature and relative humidity profiles at various levels. Weight: 21 pounds. Clock and command system used to operate sensor systems. Stabilization in three attitudes provided by ACS employing horizon scanners, coarse sun sensors, yaw gyro, reaction wheels, and freon gas jets. S-band transmitter utilized for photo transmission. Power supply included 10,500 n-on-p solar cells averaging 211 watts output supplemented by the two SNAP-19 generators. Passive thermal control provided by 32 layers of aluminized insulating material; active thermal control provided by bellows-actuated louvers and six thermal strip heaters. SNAP-19 experiment consisted of two radioisotope-fueled thermoelectric generators, each weighing about 28 pounds and mounted one atop the other; was to produce about 50 watts of power to supplement solar panels. Rate Measuring Package, consisting of a single degree of freedom rate integrating air bearing gyro with assorted conditioning, command, control, and telemetry electronics, was intended to assess performance of an air-bearing gyro package under orbital conditions. Provisions were also made to use this package as backup for control-subsystem gyro. Secor 13: 12-pound solid state transponder employed to retransmit signals from four ground stations – three at known locations and a fourth at position to be determined from satellite range measurements. Magnetic stabilization utilized to null out spin; telemetry system carried to monitor satellite performance.

Project Results – Nimbus III was launched April 14, 1969 from Vandenberg AFB after two delays, one caused by a propellant leak in the Agena, the other due to a launch priority at the range. Nimbus III: transmission of data from seven meteorological experiments was as scheduled; was not interrupted by a malfunction of one of two tape recorders in the pulse code telemetry transmitter system, since the recorder was to serve primarily as backup data storage. Secor 13: all systems and payload functioned normally.

Major Participants – Nimbus III: spacecraft management, prime contractor, and chief experiment supplier: NASA Goddard Space Flight Center (GSFC), Spacecraft structure, antennas, attitude control system, and integration and test contractor: General Electric. Experiments and experimenters: GSFC – IRIS, HRIR, MRIR, MUSE, IDC, RMP; SIRS – ESSA; SNAP-19 – AEC; and IRLS – GSFC in cooperation with other groups including NASA, AF Air Weather Service, various USN organizations, Woods Hole Oceanographic Inst., Bureau of Commercial Fisheries, and ESSA. Secor 13 management:

U.S. Army Topographical Command. Prime spacecraft contractor: Cubic Corp.; multi-attitude transponder built by ITT Federal Laboratories. Launch vehicle management: NASA Lewis Research Center; first stage contractor, McDonnell Douglas; second stage, Lockheed.

Key Spacecraft Personnel		Affiliation
PM	H. Press	NASA-GSFC
PS	W. P. Nordberg	NASA-GSFC
CO	G. J. Delio	NASA-GSFC
CO	P. J. Crossfield	NASA-GSFC
SC	M. Tepper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Solar Ultraviolet Monitor	PI	D. E. Heath	NASA-GSFC
High Resolution Iridium Radiometer	PI	G. T. Cherrix	NASA-GSFC
Iridium Interferometer Spectra	PI	R. A. Hanel	NASA-GSFC
	OI	L. Chaney	University of Michigan
Sat. Iridium Spectra	PI	D. R. Wark	NOAA-NESS
	OI	D. T. Hilleary	NOAA-NESS
Medium Resolution Iridium Radiometer	PI	A. W. McCulloch	NASA-GSFC
Image Dissector Camera	PI	G. A. Branchflower	NASA-GSFC
Interrogat + Rec. + Locator System	PI	C. E. Cote	NASA-GSFC
	OI	G. Hogan	NASA-GSFC
Snap-19 Isotope Power Generator	PI	C. F. Baxter	Nuclear Regulatory Commission
Systematic Nuclear Auxiliary Power	PI	Unknown	Unknown
Animal Tracking Experiment	PI	H. Beuchner	Smithsonian Institution

APOLLO X

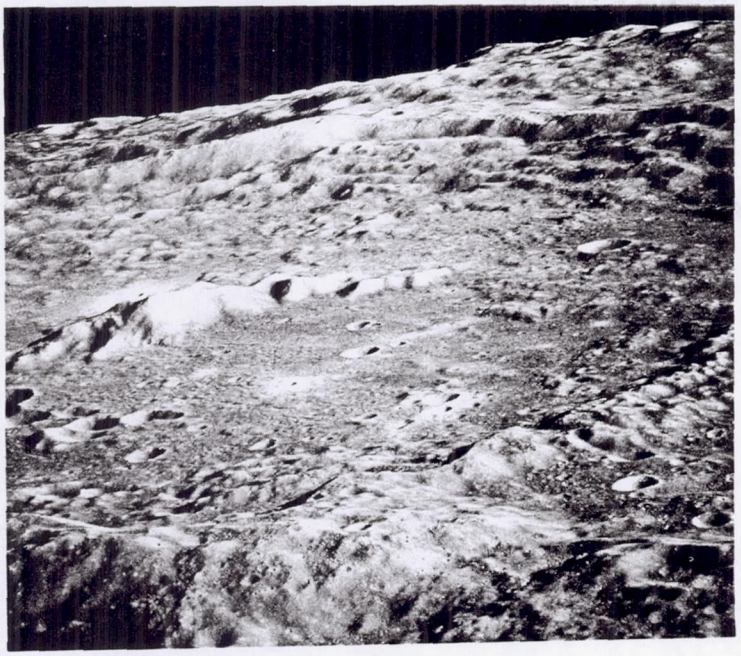
Launch Vehicle – Saturn V (AS-505) basically similar to Saturn V used to launch Apollo IX, but S-IC first-stage yielding 7.68 million pounds of thrust, S-II second stage up-rated again to 1.17 million pounds of thrust; with S-IVB third stage down-rated to 203,615 pounds of thrust. Other differences included minor modifications to the number and designs of integrated vehicle instrumentation and dry stage weights.

Spacecraft Description – Apollo X spacecraft module sections basically similar to those of Apollo X, above, with these differences: "Charlie Brown" consisted of CM 106 which was 11 feet 5 inches high and weighed 12,277 pounds, and SM 106 that was 24 feet 7 inches high and weighed 51,371 pounds; the SLA weighed 4000 pounds; LM ("Snoopy") consisted of a descent stage that weighed 4703 pounds "dry," 22,837 pounds with propellants, and an ascent stage that weighed 4781 pounds "dry," 8012 pounds with propellants.

Project Objectives – Primary objectives of the Apollo X flight: an eight-day mission to encompass all aspects of an actual manned lunar landing except the landing; the first flight of a complete, manned Apollo spacecraft to operate around the Moon; a scheduled eight-hour lunar orbit of the separated LM, only the second manned LM flight; and the LM to descend to about nine miles of the Moon, before ascending for rendezvous and docking with the CSM in about a 70-mile circular lunar orbit. Pertinent data to be gathered in this landing rehearsal dealt with the lunar potential (gravitational) effect, to refine the Earth-based Manned Space Flight Network tracking techniques and to check out LM programmed trajectories and radar and lunar flight control systems. Twelve television transmissions to Earth were planned.

Spacecraft Payload – Apollo X payload and equipment was basically similar to Apollo IX, with the following comments. CSM 106, as will be all subsequent modules, was equipped with a VHF ranging device as a backup to the LM rendezvous radar. The LM 4 communication system was modified from that for LM 3 on Apollo IX: real-time commands to the LM were received and encoded by a digital uplink assembly connected with the S-band receivers; an S-band command system was used and will be used on all subsequent LM's, replacing the UHF receiver used on Apollo IX; and there were no C-band or scimitar antennas. Apollo X crewmen were Commander Thomas P. Stafford, Command Module Pilot John W. Young, and Lunar Module Pilot Eugene A. Cernan. Stafford, an AF Colonel, was 38; Young, a USN Commander, also was 38; and Cernan, also a naval Commander, was 35. The television equipment on board Apollo X included both a black and white and, for the first time, a color television camera. The B&W camera was a 4.5-pound camera similar to that flown on Apollo VIII, with an 80-degree field-of-view wide-angle lens, producing a 227-line-scan signal at 10 frames per second. The color TV camera was a 12-pound hand-held camera with a zoom lens for closeup or wide angle use, and a three-inch monitor that could be mounted on the camera or within the CM; the camera produced a 525-line, 30-frame-per-second signal in color by use of a rotating color wheel. Still camera equipment, excluding the multispectral experiment, was the same as for Apollo IX.

Project Results – Apollo X was launched from Cape Kennedy on May 18, 1969 into a nominal 115-mile circular Earth-parking orbit, at an inclination of 32.5°, the orbital vehicle comprising the S-IVB stage and its payload of the CSM, the LM, and its SLA shroud. One and one-half orbits later, trans-lunar injection occurred. The S-IVB was fired to increase velocity from 25,593 to 36,651 feet per second on a free-return trajectory; 25 minutes later the CSM was separated for transposition and docking with the LM, similar to the maneuver performed on Apollo IX. The first live color TV transmission to Earth, showing the docking process and the interior of the CSM, began three hours after launch when Apollo X was 3570 miles from Earth and concluded when the spacecraft was 9428 miles away. About four hours after launch, Apollo X separated from the S-IVB stage, which was followed by another telecast from 14,625 miles out. A third TV transmission of pictures of Earth was made from 24,183 miles out, and a fourth telecast of the Earth was made from 140,000 miles. The launch trajectory had been so satisfactory that only one of four midcourse corrections was needed; this was accomplished 26.5 hours into the flight. About 76 hours into the mission, lunar-orbit insertion occurred with the firing of the SPS. A second firing of the engine 4.5 hours later circularized the lunar orbit of Apollo X at approximately 69 miles, which was followed by the first color TV pictures to Earth of the Moon's surface. Stafford and Cernan entered the LM and prepared for the undocking maneuver that occurred on the 12th revolution, just over 98 hours into the flight. At about 100 hours, on May 22nd, the vehicles separated and briefly flew a stationkeeping lunar orbit of 66.7 by 71.5 miles, before initial firing of the LM descent engine for 27.4 seconds – with 10 percent thrust for the first 15 seconds and 40 percent thrust for the rest – to achieve a new orbit for the LM of 9.7 by 70.5 miles, a simulation of the Apollo XI lunar landing mission. The LM flew over landing site 2 in the Sea of Tranquility; during this run, the LM landing radar was tested for altitude functioning, providing both "high gate" and "low gate" data. Following a 7.5-second firing of the LM RCS thrusters, the descent engine was fired in two bursts for 40.1 seconds – at 10 percent and at full throttle – placing the LM into an orbit of 13.7 by 219 miles. On the 14th revolution, it reached a pericynthion of 12.7 miles and was "staged." The descent stage was jettisoned on a second attempt, and an uncontrollable gyration of the ascent stage occurred. It was later attributed to an error in a flight-plan checklist, causing an incorrect switch position. The ascent engine was fired for 15 seconds, lowering the LM apocynthion to 53.8 miles, 230 miles behind and below the CSM. The RCS thrusters were fired for 27.3 seconds when the LM was 16.9 miles below the CSM and 170.4 miles behind, yielding an orbit of 54.4 by 48.1 miles. To prepare for the terminal phase of rendezvous, the RCS were fired again, resulting in an orbit of 17.2 by 81.7 miles. Stafford sighted the CSM's running lights at about 48 miles. The 15-second terminal phase initiation firing reduced velocity as the LM entered an intercept trajectory and the two vehicles achieved stationkeeping on the 16th lunar revolution. With Young in the CSM effecting an active rendezvous role, the vehicles were re-docked on May 23rd, slightly over 106 hours into the mission. The LM ascent stage was jettisoned and its engine fired to depletion. The rest of the time in lunar orbit was spent on landmark tracking and photography. On the 31st orbit the SPS was restarted while Apollo X



This photograph was taken from the Apollo X Command and Service Modules on the lunar farside of International Astronomical Union crater No. 302 at an altitude of 60 nautical miles.

was on the back side of the Moon, and Apollo X was injected into a trans-earth trajectory. After a midcourse correction, and CM-SM separation, Apollo X re-entered on May 26, 1969 and splashed down 165°W., 5°8′S., within television range of the recovery ship, completing a flight of 192 hours three minutes 23 seconds; one minute 24 seconds longer than planned. The Apollo X S-IVB third stage and LM ascent stage went into solar orbits; the LM descent stage went into a selenocentric orbit.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell, CM and SM spacecraft prime contractor; SPS, Aerojet-General, principal and subcontractors; AVCO, ablative heat shield; Collins, communication and data subsystems; Garrett, environmental control system; Grumman, LM spacecraft prime contractor; PGNS, General Motors (manufacturing), MIT (technical management), principal and subcontractors; NR, ascent engine; RCA, communication subsystem and radar and control electronics; TRW, descent engine and abort guidance system; IBM, IU prime contractor; Boeing, Apollo/Saturn V technical integration and evaluation; GE, Apollo checkout equipment, related engineering design, quality management, and engineering support; TRW, mission trajectory control and spacecraft system analysis; NASA Marshall Space Flight Center, launch vehicle management; Boeing, first stage prime contractor; NR, second stage; McDonnell Douglas, third stage; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, Manned Space Flight Network management.

Key Spacecraft Personnel		Affiliation
PM	S. C. Phillies	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Photos 70 MM and 16 MM	PI	R. J. Allenby, Jr.	NASA Headquarters
	OI	J. H. Sasser	NASA-JSC

OGO VI

Launch Vehicle – Thorad-Agena D (uprated version of the Thrust-Augmented Thor, used in connection with an Agena second stage, with greater tank volume than previous vehicles): 170,000-pound-thrust Thor first stage augmented by three strap-on solid rocket motors providing 52,130 pounds of thrust; Agena D second stage, 16,000 pounds of thrust. Height 109.5 feet.

Spacecraft Description – Essentially, configuration identical with OGO V: main body was rectangular, six feet long, three feet wide, three feet high; with appendage deployed was 49 feet long and 20.5 feet wide. Appendages included two 22-foot booms carrying experiments which required positioning away from magnetic effects of main body; four four-foot experiment-bearing booms, on three of which were mounted telemetry antennas to achieve improved patterns made possible by such spacing; rotatable, box-like Orbital Plane Experiment Packages (OPEP's) nominally either 18 inches long, 10 inches high, and 9 inches deep, or 15 by 9 by 13 inches, and positioned at various locations and distances from the main body; and two solar panels six feet wide by eight and one-half feet long, having approximately 80 square feet covered with 33,000 n-on-p cells. Solar Oriented Experiment Packages (SOEP's) were also mounted on the solar panels. Heaviest OGO, weighing 1393 pounds.

Project Objectives – Planned for a period of maximum sun spot activity, to conduct experiment measurements in the Earth's upper atmosphere and ionosphere, the auroral regions surrounding the poles, and the edges of the regions of trapped radiation. Emphasis placed on investigating interrelationships between particle activity, aurora and airglow, geomagnetic field, neutral and ionized composition, wave propagation and noise, and the input solar energy contributing to ionization and heating. Data gathered over global range from the equator to the poles.

Spacecraft Payload – OGO VI had greater storage rates and command capabilities than previous OGO's, and carried 371 pounds of instrumentation for the 25 experiments contributed by 10 universities, four government agencies, five private companies. Experiments designed to correlate investigations in solar, aeronomy, energy particle, auroral, and airglow physics. Atmospheric and ionospheric experiments included seven packages to study atmospheric density, electron temperature and density, neutral atmospheric composition, atmospheric ion concentration and mass, and ionospheric ducting, and an energy transfer probe. Solar radiation measurements included three packages to study X-ray emissions, and to survey and monitor solar ultraviolet emissions. Ten airglow and auroral studies to measure: emissions; spatial distribution and variations; celestial lyman-alpha radiation, globally; sodium airglow; low energy auroral particles; measurements of trapped and precipitated energy particles; low-energy solar cosmic rays; and galactic cosmic rays. Magnetic and electrical field studies included: the creation and alteration of the main geomagnetic field, fluctuations, ionospheric intensity and gradient measurements, VLF polarization and wave-normal direction, and whistler and low-frequency studies. Two solar arrays and two 12-ampere-hour DC nickel cadmium batteries provided maximum power output of about 560 watts. Three-axis, five-degrees-of-freedom stabilization provid-

ed by a combination of horizon scanners, sun sensors, gas jets, electrically-driven flywheels (utilized to store and dump momentum), and associated electronics. Combined active and passive thermal control system utilized heaters, radiating panels, and 101 aluminum louvers on three sides. Communications and data handling system provided for tracking and command, and transmitted experiment data in real-time or stored up to 24 hours of data.

Project Results – OGO VI was launched June 5, 1969 from Vandenberg AFB into an orbit of 248 by 683 miles, at an inclination of 81.9°. Deployment and sun acquisition began after separation from Agena second stage and was confirmed 1½ hours after liftoff. Twenty-three of 25 experiments functioned perfectly; two experiments failed: the ion mass spectrometer for measuring ion concentrations along the orbital path; and the celestial lyman-alpha experiment.

Major Participants – NASA Goddard Space Flight Center, spacecraft management; TRW, spacecraft prime contractor; GSFC, Lockheed, Universities of Michigan, New Mexico, Colorado, California at Los Angeles, New Hampshire, Stanford and Pittsburgh, as well as the University of Paris, France, JPL, Dartmouth College, Southwest Center for Advanced Studies, Faraday Laboratories, U.S. Naval Research Lab, and Air Force Cambridge Research Lab., experimenters; NASA Lewis Research Center, launch vehicle management; McDonnell Douglas, first stage contractor; Lockheed MSC, second stage.



OGO VI was launched June 5, 1969 to investigate the Earth's solar, aeronomy, energy particle, auroral, and airglow physics.

Key Spacecraft Personnel		Affiliation
PM	W. E. Scull	NASA-GSFC
PS	N. W. Spencer	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Microphone Atmosphere Density Gauge	PI	G. W. Sharp	NASA Headquarters
	OI	T. J. Crowther	Unknown
Langmuir Probes	PI	A. F. Nagy	University of Michigan
	CO	W. E. Althouse	California Institute of Technology
	OI	L. H. Brace	NASA-GSFC
Planar Ion Trap	PI	W. B. Hanson	University of Texas, Dallas
	OI	T. W. Flowerday	Unknown
Neutron Atmosphere Comp. Quadrap. Analyzer	PI	C. A. Reber	NASA-GSFC
	OI	D. N. Harpold	NASA-GSFC
	OI	G. R. Carignan	University of Michigan
	OI	D. R. Taeusch	University of Michigan
Atmosphere Mass Spectrometer	PI	H. A. Taylor, Jr.	NASA-GSFC
	OI	R. A. Pickett	NASA-GSFC
	OI	F. R. Allum	University of Texas, Dallas
Ion Mass Spectrometer	PI	W. B. Hanson	University of Texas, Dallas
	OI	T. W. Flowerday	Unknown
Energy Transition Probe Atmospheric Density	PI	D. McKeown	Faraday Laboratory
	OI	H. R. Poppa	General Dynamics
Solar X-Ray, 0.15-6.2A	PI	R. W. Kreplin	U.S. Naval Research Laboratory
	OI	T. A. Chubb	U.S. Naval Research Laboratory
	OI	H. D. Friedman	U.S. Naval Research Laboratory
	OI	C. S. Bowyer	University of California, Berkeley
Solar Ultraviolet 170-1700A	PI	D. E. Bedo	USAF Geophysical Laboratory
	OI	H. E. Hinteregger	USAF Geophysical Laboratory
Solar Ultraviolet 1800-3200A	PI	V. H. Regener	University of New Mexico
Airglow + Auroral Emissions	PI	J. E. Blamont	CNRS-SA
Lyman-Alpha Photometer	PI	M. A. Clark	Aerospace Corporation
	OI	D. D. Elliott	Executive Office of the President
	OI	P. H. Metzger	Aerospace Corporation

Experiment	Experiment Personnel		Affiliation
Ultraviolet Photometer 1304A + 1216A	PI	C. A. Barth	University of Colorado
	OI	J. B. Pearce	Science Applications, Inc.
	OI	E. F. Mackey	Packard-Bell Corporation
Shape Line 6300A Airglow	PI	J. E. Blamont	CNRS-SA
Auroral E + P, 1-20 keV	PI	D. S. Evans	NOAA-ERL
	OI	D. E. Stillwell	NASA-GSFC
Trapped + Precipitating Electrons	PI	T. A. Farley	University of California, Los Angeles
	OI	M. C. Chapman	TRW Systems Group
Trapped + Precipitating Electrons SSDT	PI	D. J. Williams	NOAA-ERL
	OI	J. H. Trainor	NASA-GSFC
Neutron Monitor	PI	J. A. Lockwood	University of New Hampshire
	OI	E. L. Chupp	University of New Hampshire
Low Energy Cosmic Ray Measurements	PI	A. J. Masley	TRW Systems Group
	OI	P. R. Satterblom	McDonnell Douglas Corporation
Cosmic Ray Experiment	PI	E. C. Stone	California Institute of Technology
	OI	R. E. Vogt	California Institute of Technology
	CO	W. F. Althouse	California Institute of Technology
Magnetic Survey Rubidium Vaporizer Magnetometer	PI	J. C. Cain	NASA-GSFC
	OI	R. A. Langel	NASA-GSFC
Triaxis Search Coil Magnetometer	PI	E. J. Smith	NASA-JPL
	OI	R. F. Holzer	University of California, Los Angeles
DC Electric Field Measurements	PI	T. L. Aggson	NASA-GSFC
	OI	N. C. Maynard	NASA-GSFC
	OI	J. P. Heppner	NASA-GSFC
VLF Receiver, 20Hz - 30kHz	PI	R. A. Helliwell	Stanford University
	OI	L. H. Rorden	Devlco Inc.
VLF Receiver, 50Hz - 540kHz	PI	T. Laaspere	Dartmouth College
	OI	M. G. Morgan	Dartmouth College
Sodium Airglow Photometer	PI	T. M. Donahue	University of Michigan
	OI	J. E. Blamont	CNRS-SA

EXPLORER XLI (IMP-G)

Launch Vehicle – Thrust Augmented Improved Delta (TAID): Thrust-augmented Thor first stage with three strap-on solid propellant Sergeant rockets for a total thrust of 333,820 pounds; 7800-pound-thrust second stage; and 5450-pound-thrust FW-4 solid-propellant third stage. Height 92 feet.

Spacecraft Description – Basically same as six previous IMP's: spin stabilized structure is an octagon platform 10 inches high and 28 inches in diameter. Extended from the body are four solar panels; four transmitting antennas extend from the top, about 16 inches long and spaced 90 degrees apart; plus 2 hinged magnetometer booms about six feet long. Weight 174 pounds.

Project Objectives – Explorer XLI was seventh of 10 programmed spacecraft in the IMP series designed to continue the basic interplanetary scientific study program during intense solar activity. Objectives included continued studies of: radiation environment of cislunar space, begun with launch of IMP-A (Explorer XVIII) in 1963; characteristics of interplanetary magnetic field and how it is affected by variations in the solar wind; continued solar-flare monitoring, supplying real-time radiation data to NASA to support Apollo XI, as earlier IMP's had supported Apollo VIII and IX; and demonstrations of state-of-the-art development of inexpensive satellites for interplanetary investigations.

Spacecraft Payload – Experiment instrumentation, the weight of which was just over 60 pounds, included 12 experiments – the most ever carried by an IMP. They were: three-axis fluxgate magnetometer, range versus energy loss detector, energy versus energy loss detector, low energy proton and alpha detector, ion chamber, low energy solar flare electron detector, solar proton monitoring experiment, cosmic ray anisotropy or angular distortion analyzer, low energy telescope, a plasma experiment, and two low-energy proton and electron differential energy analyzers. Spacecraft supportive systems included spin stabilization, PFM telemetry with 4-watt transmitter and digital data processor, and power supply of 70 watts provided by 6144 solar cells and 13 silver cadmium batteries.

Project Results – Explorer XLI was launched June 21, 1969 from Vandenberg AFB into a nominal 210 by 132,885 mile orbit at an 83.8° inclination, and continued returning data on cislunar radiation phenomena.

Major Participants – NASA Goddard Space Flight Center, project management and spacecraft designer, experimenter; Bell Telephone, Universities of California, Chicago, Maryland, State Univ. of Iowa, and Applied Physics Laboratory of Johns Hopkins Univ., experimenters; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	P. Butler	NASA-GSFC
PS	F. B. McDonald	NASA-GSFC
CO	A. W. Schardt	NASA Headquarters
CO	B. H. Ferer	NASA-GSFC
CO	H. H. Levy	NASA-GSFC
CO	D. Stewart	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Low Energy Telescope	PI	W. L. Brown	Bell Telephone Laboratories
	CO	L. J. Lanzerotti	Bell Telephone Laboratories
	OI	C. S. Roberts	Bell Telephone Laboratories
	OI	G. I. Miller	Bell Telephone Laboratories
Ion Chamber	PI	K. A. Anderson	University of California, Berkeley
	OI	G. H. Pitt	University of California, Berkeley
	OI	R. P. Lin	University of California, Berkeley
C. R. Protons (R vs DE/DX)	PI	J. A. Simpson	University of Chicago
	CO	G. Lentz	University of Chicago
Lepeda, Low Energy Proton + Electron	PI	L. A. Frank	University of Iowa
	OI	J. A. Van Allen	University of Iowa
Cosmic Ray Anisotropy	PI	K. G. McCracken	CSIRO
	OI	U. R. Rao	Isro Satellite Center
	OI	W. C. Bartley	National Academy of Sciences
Electronic Analyzer (RPL. BY 12 + 13)	PI	F. B. Harrison	Unknown
Solar Proton Monitor	PI	C. O. Bostrom	Applied Physics Laboratories
	OI	D. J. Williams	NOAA-ERL
	OI	D. E. Hagge	Unknown
	OI	F. B. McDonald	NASA-GSFC
Electrostat Plasma Analyzer	PI	K. W. Ogilvie	NASA-GSFC
	OI	T. D. Wilkerson	University of Maryland
Low Energy Proton + Alpha Detector	PI	F. B. McDonald	NASA-GSFC
	OI	G. H. Ludwig	NOAA-NESS
Cosmic Rays (E vs DE/DX)	PI	F. B. McDonald	NASA-GSFC
	OI	G. H. Ludwig	NOAA-NESS
Magnetic Field Experiment	PI	N. F. Ness	NASA-GSFC
	OI	D. H. Fairfield	NASA-GSFC
Channeltron Particle Detector	PI	K. A. Anderson	University of California, Berkeley
Second Lepedea	PI	L. A. Frank	University of Iowa

BIOSATELLITE III

Launch Vehicle – Long Tank Thrust-Augmented Delta N (two-stage), orbited the heaviest spacecraft yet launched by a Delta: first stage with three strap-on solid propellant motors and a total thrust of 328,000 pounds and 7800-pound second stage. Both stages autopilot guided. Height 106 feet.

Spacecraft Description – Similar to Biosatellites I and II: seven feet long, comprised of three major segments – adapter, re-entry vehicle, and recovery capsule. Adapter was a 57-inch-diameter cylinder with the forward end tapered to a 40-inch-diameter open interface, coupling it to the re-entry vehicle. Adapter contained housekeeping equipment and the life-support and experiment-support systems, including a system to provide the recoverable capsule with a two-gas atmosphere resembling the Earth's air at mean-sea-level pressure, a first for a U.S. biological satellite. Capsule atmosphere consisted of nitrogen (80 percent) and oxygen (20 percent) provided from storage tanks; pressure sensors and valves maintained normal atmospheric pressure of 14.7 psi; two thermostatically-controlled, low-flux heaters on capsule walls kept atmosphere temperature at 75°F. Commands for satellite or experiment operations came from the ground or from six onboard programmer-timers in the re-entry vehicle. One 2-watt telemetry transmitter plus digital sampling and coding equipment were located in the adapter unit for housekeeping data during the mission, with a duplicate set in the primate capsule to return similar data after separation. Orbital telemetry was sent in PCM mode; de-orbit telemetry sent in an FM-FM mode. Sample data on the mission was stored by the seven-channel, 87-hour tape recorder in the capsule. Electrical system consisted of a fuel cell, inverters, converters, regulators, distribution circuits, and a silver zinc battery in the adapter with smaller batteries for power during retrofire and recovery. Temperature was controlled by two means: a circulating liquid system, with heated water being used to heat selected experiments before it was re-cooled; and a passive system, which held internal temperatures in the adapter between zero and 100°F, composed of a 28-inch layer of aluminized mylar attached to the vehicle skin with cutouts to allow for dissipation. In-orbit stabilization so that rotational forces were less than 1/100,000 g and re-entry position control both were provided by an attitude control system, which comprised high-pressure nitrogen gas, three motion-sensing gyros, and six cold-gas thruster jets. Re-entry vehicle contained the recoverable capsule, separation, and the entry systems. It consisted of a bowl-shaped fibrous glass heat shield 40 inches in diameter, with an ablative surface material of phenolic nylon and an aft thermal cover protecting the recovery equipment. A thrust cone nested into the aft end of the heat shield and carried a retro-rocket and cold-gas spin jets. Recovery capsule was a blunt aluminum cone, slightly smaller than the re-entry vehicle, mounted inside the heat shield; had 9 cubic feet of internal volume, provided life support for the primate, and housed experimental and recovery equipment, including a radio beacon for backup sea recovery. Combined weight: 1536 pounds.

Project Objectives – Whereas Biosatellites I and II orbited many of less complex life forms for experimentation in space, Biosatellite III was to conduct the most intensive series of concurrent experiments with a single, highly complex living organism for a period of from two weeks up to 30 days or

longer. Investigations concentrated on evaluating the effects of weightlessness in space on mental, emotional, and physiological processes and physical dexterity of species of monkey that is similar to man in major organ systems and in general aspects of brain organization and cardiovascular functions, but somewhat more resistant to stress and capable of more rapid healing. The flight monkey weighed 14 pounds and was 31 inches tall. Post-flight experiments were also central to the mission and included comparisons with pre-flight measurements of the following: body cell mass – a count of the number of body cells by measuring the amount of naturally radioactive potassium in the monkey's body; red blood cell volume – achieved by measuring injected radioactive chromium 50 that attaches to red cells; plasma volume; total body water – achieved by measuring the proportion of radioactive water, injected into the body; extracellular fluid (including plasma); intra-cellular fluid, hemoglobin content and plasma protein content; and more than 30 biochemical analyses of urine and feces, including for steroids, calcium, and phosphorus. Five sets of X-rays were made periodically from 14 days before the flight, to obtain baseline data on skeletal mineral present in spine, hands, arms, feet, pelvis, and leg bones. After flight the primate was to be X-rayed again at four, seven, 14, 30, and 60 days to measure the rate of recovery of any bone mineral lost during the flight due to weightlessness. Post-flight studies to testicular tissue and spermatozoa were to be made to determine possible changes in tissue and several types of reproductive cells during the flight. Sperm and pre-sperm cells were checked for numbers, mobility, morphology, and viability. The flight plan called for either a mid-air aircraft retrieval of the re-entered primate capsule during parachute descent over the Pacific Ocean, or for retrieval from the ocean.

Spacecraft Payload – Experiments in the space laboratory included twenty-four physical measurements recorded simultaneously on a primate (a pigtail monkey, native to Malaysia and Thailand, Macaca nemestrina) that carried out scheduled activities. Detailed studies of brain functions in weightlessness, the first ever made, were made when the primate experienced sleep, wakefulness, anxiety, and boredom, and the performance of two difficult tasks, one testing short-term memory and the other, eye-hand coordination. Eighty percent of the experimental data was telemetered at 22,400 data bits per second from 18 to 26 times a day. Four important advances were made in preparing for this spaceflight experiment; they included an "error-free" teaching system, a shoe-box-sized automatic urinalysis laboratory, a new method of surgically implanting and securing a permanent urinary catheter, and a new technique for computer pattern-recognition of complex physiological data. Instrumentation implanted in the monkey's body included ten electroencephalographic (EEG) leads surgically placed in the brain six months prior to flight which permitted monitoring of the planning, recent memory, alertness, long-term drives (fear, rage, sex), sleep, and other characteristics. The leads were placed in these regions: frontoparietal, frontotemporal, occipital, hippocampus, amygdala, mid-brain, and centrum medianum. An eleventh brain sensor monitored brain temperature. Two sensors monitored eye motion. Two sensors in neck and back muscles monitored muscle tension and activity. Two sensors under the skin on each side of the chest provided electrocardiogram (EKG) and respiration data. Four catheters

monitored blood pressure in the principal veins and arteries, and one in the bladder permitted three types of urine analyses four times a day. About 50 different kinds of biochemical metabolic effects measurements were made through pre- and post-flight analyses of blood, urine, and feces. The monkey's water supply, manufactured in the fuel cell by oxygen and hydrogen gas, was pumped to the water accumulator tank and from there to a small (30 cc) tank with steel nipple attached, which the monkey emptied by sucking on the nipple. The tank was filled automatically once an hour during the 12-hour day and once every three hours at night, for a daily maximum of 480 cc (about one pint), which could be increased to 720 cc (a pint and a half) per day on the ground command. Ingoing water was metered, and the primate's water consumption radioed to the ground continuously. Urine (about 400 cc per day) was channeled directly from the primate's bladder through a catheter between the genitals and the rectum, and to the storage tank in the adapter. A portion of it was passed through the urinalysis device, with a small (100 cc) urine tank in the capsule to allow urine collection during recovery. Meals came in the form of square pellets, each weighing about two grams, issued up to 60 pellets (120 grams) per day. There were 1840 pellets stored on eight reels of perforated tape. Some food was awarded for performing the two behavioral tasks, conducted in twice-a-day, repetitive 15-minute cycles. The tasks, taught to the monkey through the 18 weeks before launch, consisted of a delayed-matching task and a visuomotor task requiring eye-hand coordination. Two successful performances at either task earned one food pellet, and the tasks were programmed for repetition to yield a maximum of 20 pellets per session. The remaining 20 pellets each day were given during a free period. Pellet consumption was monitored and telemetered regularly. The primate's stool (about 40 grams per day) passed through a hole in the bottom of the couch and transported in zero gravity by a flow of air to the storage bin under the couch. Gasses were passed out of the bin through a bacteria filter, and processed by the atmosphere system. Primate-capsule equipment and facilities were as follows: the primate was seated on a hammock-like couch about 27 inches long, in a space 26 by 10 by 10 inches, with some additional front and side alcoves up to five inches deep, and a headrest. He wore a vest-like nylon-cotton jacket that had an apron extending down over his legs. This suit was zipped to the couch and laced to the side rails. This restraint system maintained the monkey in position during high-g launch and re-entry; had no pressure points to cause sores on a long flight; it allowed motion of arms and legs but prevented him from tampering with urinary and blood pressure catheters and other sensors; and it allowed him to easily operate food and water dispensers and to perform tasks. Day and night for the monkey were 12 hours each. Day was simulated by an incandescent white light of six to ten foot candles. Night was a deep red light, 30 times dimmer than the daytime light. A camera with 13,000 frames of 16 mm film used these lights to take one black-and-white photograph of the monkey's head every 20 minutes (day or night), from liftoff to de-orbit. It took motion pictures at four frames per second for 20 minutes during launch, for seven minutes during capsule separation and re-entry, and for nine two-minute periods during orbit.

Project Results – Biosatellite III was launched on June 29, 1969, from Cape

Kennedy into an orbit of 221 by 240 miles at an inclination of 33.5°. Spacecraft's re-entry vehicle was de-orbited and the mission curtailed on July 7, after nine days and 130 revolutions, because the primate's metabolic condition was rapidly deteriorating and it was hoped to recover the primate alive. From a 73% success rate of the launch pad in one of the two tests to be performed in space, the monkey's rate fell to 27% and 23% on both tests while in orbit the third day. He refused to consume water beginning July 6, experienced lower body temperature and reduced heart rate, increased his sleep, and showed shallow breathing. It was reported that blood pressure in the thorax region of the animal had risen for six consecutive days then declined sharply. This produced extensive loss of fluids through urine and perspiration and resulted in a 21 percent dehydration. The decision to recover the capsule was made July 7, after one million bits of data were telemetered to Earth during the flight. During re-entry, the satellite was pitched downward 36 degrees and positioned backward, with two infrared horizon scanners providing data to align the vehicle in pitch and roll to the de-orbit attitude while yaw was ground-controlled. Separation of the recoverable capsule and adapter and entry procedures were initiated by programmed switches. Two seconds after separation, the re-entry vehicle was spun to 60 rpm, 10 seconds of thrust were provided by the 1000-pound-thrust retro rocket, and the vehicle was despun to 12 rpm; following this, the thruster was separated and the vehicle turned heat-shield-forward by aerodynamic drag. Seventeen minutes after retrofire at 80,000 feet, the 19-square-foot drogue parachute deployed, and 10 seconds later the reefed main chute deployed to 72 square feet, which then was disreefed to open to 505 square feet. A mid-air retrieval was missed when the capsule was lost in the clouds and it splashed down 25 miles north of Kauai, Hawaii. A radio recovery beacon provided for backup sea-landing recovery enabled scuba divers to locate and connect the capsule to a helicopter for a flight to a temporary laboratory at Hickam AFB. Following recovery the monkey was revived but died unexpectedly within 12 hours presumably from a massive heart attack brought on by dehydration. The mission was judged a partial success, since more than 80 percent of the data expected for a full 30-day planned mission was to have been obtained from space telemetry with only 20 percent relegated to post-flight examination concentrated within a 60-day period.

Major Participants – NASA Ames Research Center, project management; General Electric, satellite prime contractor; UCLA Brain Research Institute, primate experiment; Univ. of Southern California, cardio-vascular monitoring; Univ. of California, Berkeley, and JPL, urinalysis and mineral protein-liquid balance; Texas Women's Univ., X-ray bone density studies; Harbor General Hospital, Torrance, Calif., reproductive system; NASA Goddard Space Flight Center, launch vehicle management; McDonnell Douglas, launch vehicle prime contractor.

Experiment	Experiment Personnel	Affiliation
Bone Mineral Loss	PI P. B. Mack	Texas Woman's University
Effects in Macaca Nemestrina	PI W. R. Adey	University of California, Los Angeles
	OI A. T. K. Crockett	Harbor General Hospital
	OI J. P. Meehan	University of Southern California
	OI N. Pace	University of California, Berkeley
	OI J. Rho	NASA-JPL

Launch Vehicle – Saturn V (AS-506), basically similar to the Saturn V used to launch Apollos IV through X, except for the integration of less but fully operational instrumentation, replacing most of the R&D instrumentation used on previous flights. Apollo XI's S-IC first stage contained five F-1 engines producing total thrust of 7.65 million pounds. The S-II second stage contained five J-2 engines yielding thrust up to 1.14 million pounds. The S-IVB third stage contained one J-2 engine generating up to 203,779 pounds of thrust at first burn, and over 200,000 pounds of thrust at second burn after separation from the docked CSM-LM configuration, for S-IVB injection into solar orbit. An Instrument Unit (IU), a cylinder three feet high and 21.7 feet in diameter, was mounted atop the third stage and contained guidance, navigation, and control equipment for combined S-IVB-CSM-LM Earth-orbit flight and for S-IVB solar orbit insertion; for these phases of the flight, the IU also contained telemetry, communication, tracking, and crew-safety systems, as well as self-supportive electrical and environmental control equipment. S-IC height, 138 feet; S-II, 81.5 feet; S-IVB, 58.3 feet. Total height, including the 28-foot Launch Escape System (LES) atop the spacecraft, was 362.8 feet.

Spacecraft Description – Apollo XI was heavier than all previous Apollo spacecraft: 96,698 pounds. The total spacecraft configuration consisted of Command Module (CM) 107 and Service Module (SM) 107 (known together as "Columbia"), Lunar Module (LM) 5 ("Eagle"), a Spacecraft-Lunar Module Adapter (SLA), and a Launch Escape System (LES) atop the CM. LES structure was an open frame tower with three solid-propellant motors: a 147,000-pound-thrust main motor mounted atop the tower; a 31,500-pound-thrust tower jettison motor; and a 2400-pound-thrust pitch control motor for bending the CM's escape trajectory away from the launch vehicle and/or pad area, in case of abort. Height of total LES, 33 feet; weight 8848 pounds (not considered part of the overall spacecraft and not included in total weight, above). CM structure was a conical pressure vessel 12 feet high, 12 feet 10 inches in base diameter, encased in heatshields and consisting of three compartments: the forward compartments contained two negative-pitch reaction control engines and components of the Earth-landing system; the crew compartment, with 210 cubic feet of habitable volume, contained crew accommodations, controls and displays, and spacecraft systems; and the aft compartment housed 12 reaction control engines and propellant tanks. CM heat shields were made of brazed stainless steel honeycomb filled with phenolic epoxy resin as ablative material, with thickness ranging from 0.7 to 2.7 inches, according to anticipated heat loads. The CM inner structure was a "sandwich" of aluminum honeycomb bonded between sheet aluminum alloy, ranging in thickness from 0.25 inch at the forward access tunnel to 1.5 inches at the base. Mounted in the CM forward tunnel was the docking probe assembly: a folding, coupling, and impact-attenuation device that mated with a conical drogue mounted in the LM docking tunnel. Probe and drogue assemblies both were removable for stowing to allow free access to the tunnels for crew transfer while the CM and LM were docked. CM weight 12,250 pounds. SM structure was a cylinder 12 feet 10 inches in diameter and 24 feet 7 inches high, with an outer skin formed of inch-thick aluminum honeycomb panels, and an interior divided by milled aluminum

radial beams into six sections around a central cylinder. The six sections contained fuel cells and on-board consumables, and fuel and oxidizer tankage for the service propulsion system (SPS) and reaction control (RCS) engines. SM weight 51,243 pounds. SLA stage structure was a 28-foot-high truncated cone tapering from 260 inches in diameter at the base to 154 inches at the forward end, where it mated with SM, with four jettisonable wall panels of 1.75-inch-thick aluminum honeycomb, and serving as a shroud for the LM and as the structural interstage between IU and SM. Weight of the SLA, 4000 pounds (not considered part of the overall spacecraft, not included in total weight given above). LM structure was an aluminum/aluminum-alloy two-stage vehicle designed for space operations only (did not have re-entry capability), 22 feet 11 inches high, consisting of separable lunar descent and ascent stages that functioned as a unit until touchdown on the Moon, following which the ascent stage acted as a single vehicle until rendezvous and docking with the CSM and crew transfer; it was then jettisoned for crew return to Earth in the CSM alone. The descent stage was an unpressurized, load-bearing, octagonal structure 10 feet 7 inches high with a main compartment 14 feet 1 inch diagonally, which increased to 31 feet after extension of the four folded landing gear struts made of crushable aluminum honeycomb, with footpads 37 inches in diameter. For three of the legs (except the forward one) surface-sensing probes extended 68 inches and signalled for descent engine shutdown on contact with the lunar surface. The descent stage center compartment housed the descent engine (DE), and was surrounded by four square equipment bays that housed DE propellant tanks and the scientific experiment payloads to be deployed on the Moon. Intermediate triangular bays contained the environmental control system (ECS) water tanks, helium and gaseous oxygen tanks, and the DE control assembly of the LM primary guidance and navigation system (PGNS). The LM structure was encased in a mylar-aluminum alloy thermal and micrometeoroid shield. An external platform ("porch"-like) was mounted on the forward outrigger below the forward hatch; a ladder for crew egress and ingress during lunar surface operations extended from the porch down the forward landing gear strut. Weight of the descent stage without propellants was 4483 pounds; with propellants, 22,583 pounds. The ascent stage, 12 feet 4 inches high, 14 feet 1 inch diagonally, consisted of three main sections; pressurized crew compartment, midsection, and unpressurized aft equipment bay. Three other substructural areas contained the ascent chamber assembly, cluster supports, and antenna supports. The cylindrical crew compartment, 235 cubic feet in volume (with a habitable volume of 160 cubic feet), was a ring-stiffened semi-monocoque structure 92 inches in diameter and 42 inches high, containing control and display panels, body and arm rests, landing aids, two triangular front windows, a 32-inch-square inward-opening forward hatch, an overhead docking window, and an alignment optical telescope. The ascent stage midsection contained the LM guidance computer, power and servo assembly, ascent engine propellant tanks, reaction control system and RCS propellant tanks, ECS, and waste management section. A tunnel ring, atop the ascent stage, meshed with the CM latch assemblies and was aligned during docking by the LM drogue and the CSM probe. The docking and crew transfer tunnel extended 16 inches downward into the midsection, was 32 inches in diameter, with an upper hatch on the inboard end of the tunnel, hinged downward and unopenable when LM was pressurized. The ascent stage also was encased in a mylar-aluminum alloy thermal and micrometeoroid shield. Weight of ascent stage "dry" was 4804 pounds; with propellants, 10,622 pounds.

Project Objectives – (A brief program review: The flight phase of NASA's Apollo program began when the combined Apollo Command and Service Modules (CSM) configurations were twice successfully launched into sub-orbital Apollo-Saturn (AS) missions, 201 and 202, by Saturn IB launch vehicles in February and August 1966. AS 203, also a Saturn IB, was flown in four orbits of the Earth in July 1966, but incorporated none of the Apollo modules. In November 1967, the Apollo IV mission flew the Saturn-Apollo (SA) 501 in the first flight test of the Saturn V booster, incorporating a Block I (Earth-orbit type) CSM, a Spacecraft Lunar Module Adapter, and a Lunar Module Test Article. Apollo IV successfully demonstrated the spaceworthiness both of the Saturn V booster and the CSM. Apollo V (AS-204), flown with the Saturn IB in January 1968, was a space flight test both of the Lunar Module (LM) descent and ascent engines, as well as the first flight demonstration of the spaceworthiness of the LM itself. Apollo VI, in April 1968, returned to the use of the Saturn V, primarily as another test of the booster. Apollo VII, in October 1968, was the first manned flight test of the Apollo spacecraft, and included evaluations of the combined operations of the Saturn, the CM and the SM, as well as exercising the NASA manned space flight tracking, command, and communication network. Apollo VIII, in December 1968, completed multiple objectives: it was the first manned spacecraft to fly in lunar orbit (for 20 hours); it demonstrated the coordinated performances for lunar missions of the CM and SM hardware (the LM was not flown); it proved the launch vehicle's lunar-injection flight capabilities and the in-flight procedures and equipment over lunar distances; it tested CSM crew performances; and exercised ground-based mission support facilities and procedures Apollo IX, in March 1969, was an Earth-orbital engineering test of a manned LM, the first manned LM flight. Apollo X, the last rehearsal for a manned lunar landing, flew an 8-day mission to orbit within 9 miles of the Moon in May 1969. It was the first complete, manned Apollo mission and included a separate 8-hour orbit of the Moon by the LM. The stage had been set: men and their machines were ready.)

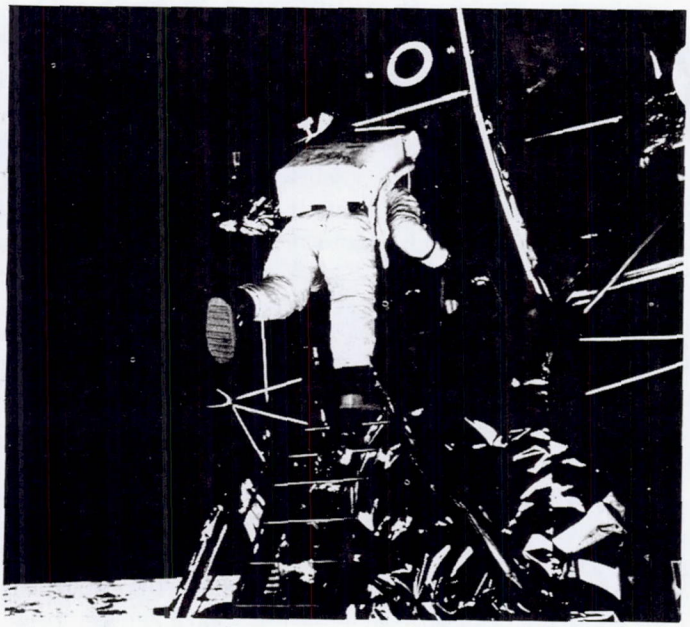
The primary objective of Apollo XI was simply stated: perform a manned lunar landing and return to Earth, completing a national goal set by President John F. Kennedy on May 25, 1961. Flight objectives additionally included an extra-vehicular scientific exploration by the LM crew, the deployment of a television camera to transmit signals to Earth during the EVA, deployment of a solar-wind-composition experiment and a seismic experiment package, which also were to transmit data to Earth, and a laser ranging reflector. During the exploration, the two astronauts were to gather samples of lunar surface materials, for return to Earth along with the solar-wind experiment, and were to extensively photograph the lurain, the deployed scientific equipment, the LM spacecraft, and each other, both with still and motion picture cameras. This was to be the last Apollo mission to fly a "free-return" trajectory that would enable, if necessary, a ready abort of the mission when the combined CSM-LM prepared for insertion into lunar orbit, by firing the SPS engine so as to merely circle behind the Moon and emerge in a trans-Earth return trajectory.

Spacecraft Payload – Spacecraft mission commander was Neil A. Armstrong, command module pilot was Michael Collins, and lunar module pilot was Edwin A. Aldrin. Armstrong, a civilian, was 38 years old; Collins, a USAF Lieutenant Colonel, was 38; and Aldrin, a USAF Colonel, was 39. Command and Service Modules (CSM) payloads included necessary mission and life-

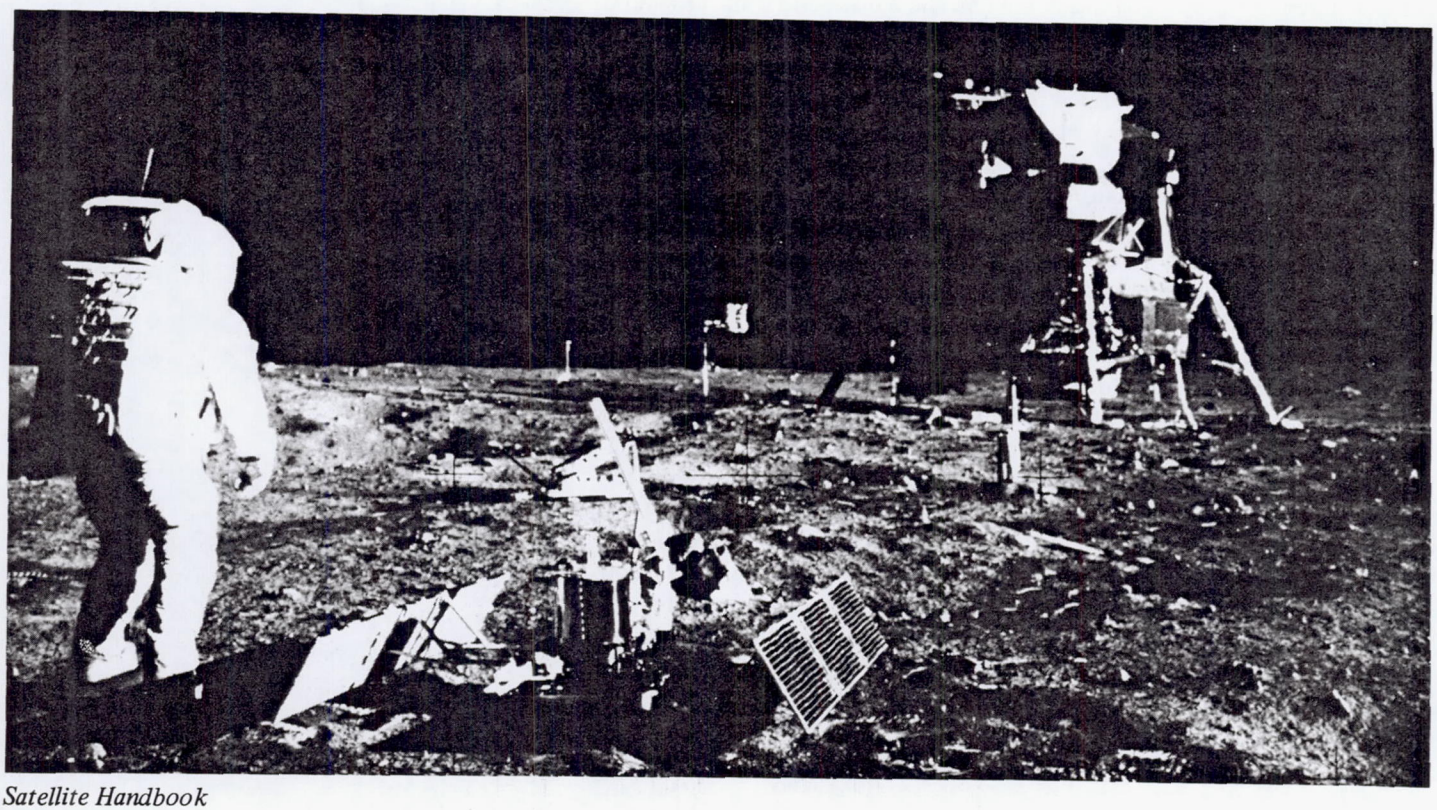
support systems and experiment equipment. An inertial and computer-based guidance and navigation system controlled position, attitude, velocity, propulsion and thrust vectors, calculated trajectories, and displayed abort data; it had backup optical equipment for celestial and landmark navigation. CSM 107 was equipped with a VHF ranging device as a backup to the LM rendezvous radar to aid in docking maneuvers. Located in the SM was a stabilization and control system that controlled rotation and translation, with crew displays provided in the CM; it backed up the guidance system. The gimbal-mounted SPS provided 20,500 pounds of thrust from re-startable hypergolic-liquid propellant engine for large velocity changes of the CSM, controlled either automatically or manually. The two RCS for the CM and SM were independent; the CM RCS consisted of two subsystems each comprising six 94-pound-thrust liquid-propelled engines; both CM RCS were activated after CM-SM separation, one being used for CM attitude control during Earth re-entry, the other for backup. The SM RCS comprised four identical clusters mounted 90° apart near the top of SM; they consisted of four 100-pound-thrust liquid-propelled engines providing redundant spacecraft attitude control, and used for small velocity change maneuvers. Twenty-eight volts of DC electrical power were generated by three 31-cell hydrogen-oxygen fuel cells in the SM, which also furnished byproduct drinking water for the astronauts. Three silver-zinc-oxide batteries located in the CM supplied power to the CM during re-entry and after landing. Two other silver-zinc-oxide batteries, isolated from the rest of the system, supplied power for vehicular separation ordnance devices and parachute deployment and separation. The CSM ECS regulated cabin atmosphere, pressure, and temperature, plus regulating CO_2, odors, particles, and ventilation of the cabin after landing; it also controlled the temperature ranges of the electronic equipment. The telecommunication system included voice, television, data, and tracking and ranging subsystems, for intercommunication between astronauts, and for Earth-spacecraft and spacecraft-LM links. Other equipment included PCM telemetry for communication with the Manned Space Flight Network ground stations; an S-band up and down link communication system for voice contact and a unified S-band tracking transponder; and a VHF recovery beacon. A high-gain, steerable S-band antenna consisted of four 31-inch-diameter parabolic dishes on a folding boom at the aft end of the SM, plus an omnidirectional antenna. Controls and displays were housed in the CM crew compartment; they were grouped by system and frequency-of-use patterns and designed for operation by crewmen wearing pressurized suits. The Earth-landing system in the CM included two reefed 16.5-foot-diameter drogue parachutes, and pilot mortar chutes to pull out three main 83.3-foot-diameter parachutes. Other CM recovery aids included an inflatable up-righting system to maintain proper CM attitude in the sea, interphone connections for recovery swimmers, fluorescent sea-dye marker, flashing beacon, and VHF transceiver. LM payload systems were independent of the CSM, providing for separate flight of vehicle. Electrical power was supplied by six silver-zinc primary batteries – four in the descent stage – providing 28 volts. The LM ECS provided atmosphere revitalization, cabin-pressure control, water management, heat control, and oxygen and water servicing of the crew's Portable Life Support System (PLSS) spacesuit backpacks. The 462 pounds of water on board the LM were contained in three nitrogen-pressurized, bladder-type tanks, one 367-pound tank in the

descent stage and two 47.5-pound tanks in the ascent stage. The communication system comprised two S-band transceivers, two VHF receivers, an S-band command system, a digital signal-processing assembly, a data storage assembly comprising a four-channel voice recorder with 10-hour capacity, and one 26-inch-diameter parabolic S-band inflight antenna, two VHF inflight dishes, an EVA antenna, and an erectable S-band antenna for the lunar surface. The LM guidance, navigation, and control system had six elements: the PGNS; abort guidance system (AGS); control electronics section (CES); orbital-rate drive electronics; and separate rendezvous radar and lunar-landing radar systems. The LM RCS consisted of four clusters of four 100-pound-thrust hypergolic-liquid-fueled engines, comprising two redundant, parallel systems; additionally, interconnect valves permitted the RCS to draw from ascent engine propellant supplies if needed. The LM descent engine (LMDE) was a pressure-fed hypergolic-liquid bipropellant engine, producing a maximum 9850 pounds of thrust, throttleable down to approximately 1050 pounds of thrust; it could be gimballed six degrees in any direction for offset center-of-gravity trimming. The ascent stage propulsion system was not gimballed and provided 3500 pounds of thrust. Tracking and docking lights were mounted on the LM: one light, mounted on the front face, which flashed once per second and was visible 150 miles to the eye (461 miles through the CSM sextant), was a contingency aid for active CSM-LM rendezvous and rescue; five docking lights analogous to aircraft running lights were mounted on the LM and included two forward yellow lights, an aft white light, and portside red and starboard green lights; all had 1000-foot visibility. Early Apollo Scientific Experiments Package, stowed in the LM's scientific equipment bay at the left rear quadrant of the descent stage, consisted of three experiments: the passive seismic experiments package and the laser ranging retro-reflector were left on the lunar surface; the solar-wind-experiment collector foil was returned to Earth. Other CSM-LM payload equipment included still, sequence, motion-picture, and television cameras. A color TV camera was in the CM, and a black and white camera was stowed in the LM descent stage for release after touchdown, activation, and transmission to Earth of Armstrong's first step for a man on the Moon, and later was deployed on a tripod for televising the EVA activities of Armstrong and Aldrin. The lunar black and white TV camera weighed 7.25 pounds, and had a scan rate of 10 frames per second at 320 lines per frame. The body was 10.6 inches long, 6.5 inches wide, 3.4 inches deep, and drew 6.5 watts of 24 to 32 volt-DC power. Two bayonet lenses, designed for interchangeability by a crewman in a pressure suit, included an all-purpose wide angle lens for closeups and large areas plus a lunar day lens for viewing sunlight-illuminated lunar surface features within the near field of view. The color TV camera was a 12-pound hand-held camera with a zoom lens for closeup or wide angle use, with a three-inch monitor that could be mounted on the camera or within the CM; the camera produced a 525-line, 30-frame-per-second signal in color by use of a rotating color wheel. Film camera equipment consisted of a 70-mm Hasselblad electric still camera in the CM, two Hasselblad 70-mm superwide angle (SWA) cameras in the LM, and a 35-mm stereo closeup camera in the LM. The SWA cameras were fitted with 38-mm lenses with a 12-inches-to-infinity range, shutter speeds up to 1/500 of a second, and a 71-degree field of view. The CM Hasselblad had three interchangeable lenses: 80 mm, 60 mm, and 250 mm. Apollo XI also car-





Apollo XI astronauts on the lunar surface. Astronaut leaves a lasting impression on lunar soil (right, top). Astronaut Edwin "Buzz" Aldrin leaves the Lunar Module (above). Aldrin sets up the Passive Seismic Experiments Package on the lunar surface (below). Lunar Module Pilot Aldrin poses for photograph taken by Neil A. Armstrong, commander (right).





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ried two Maurer 16-mm data acquisition sequence cameras – one in the CM, one in the LM – with frame speeds ranging from one to six, 12, and 24 fps. The CM camera lenses had focal length from five to 18 and 75 mm, while the LM camera had an 18-mm wideangle lens. The historical significance of the mission was not overlooked in the Apollo XI payload. Four-by-six-inch flags of 136 nations, the 50 United States, the District of Columbia, and the four U.S. possessions were carried to the Moon and back. These were in addition to three U.S. flags on board the craft – one to be deployed on the Moon, and two five-by-eight-foot flags to be returned for presentation to the U.S. Congress. Attached to the descent stage was a commemorative plaque signed by President Richard M. Nixon and the three astronauts. Another memorial to be left on the Moon was a one-and-half inch silicon disk containing microminiaturized goodwill messages and statements by Presidents Eisenhower, Kennedy, Johnson, and Nixon, as well as from 73 countries, and listings of the names of congressional and NASA leaders. Commemorative medallions were left on the Moon, bearing the names of the three U.S. Apollo astronauts who lost their lives in a launch pad fire in 1967 (White, Grissom, and Chaffee), as well as of the two USSR cosmonauts (Gargarin and Komarov) who had lost their lives in accidents.

Project Results – It is estimated that about 530-million people watching television sets around the Earth saw Neil Armstrong's televised image and heard his voice describe the event as he took ". . . one small step for a man, one giant leap for mankind," on July 20, 1969. This successful accomplishment of the Apollo program's primary objective began when Apollo XI was launched from Cape Kennedy on July 16, 1969, into an initial Earth-orbit of 114 by 116 miles. After two hours 44 minutes and one-and-a-half revolutions, the S-IVB stage was re-ignited for a second burn of five minutes 48 seconds, and Apollo XI entered translunar orbit. Thirty-three minutes later, the CSM Columbia separated from the S-IVB stage, which included the SLA containing the LM Eagle. After transposition, and jettisoning of the SLA panels on the S-IVB stage, the CSM docked with the LM. The S-IVB stage was separated and injected into heliocentric orbit, some four hours 40 minutes into the flight. During the translunar coast of the docked CSM-LM, the first color TV transmission to Earth from Apollo XI was made. Later, on July 17, a three-second burn of the SPS was made to perform the second of four scheduled mid-course corrections programmed for the flight; the launch had been so successful that the other three were not needed. On July 18, Armstrong and Aldrin put on their spacesuits and climbed through the docking tunnel from the Columbia to the Eagle to check out the LM, and the second TV transmission was made. On July 19, after Apollo XI had flown behind the Moon out of contact with Earth, the first lunar orbit insertion maneuver was made, at about 75 hours 50 minutes into the flight, with a retrograde firing of the SPS for 357.5 seconds placing the spacecraft into an initial elliptical lunar orbit of 69 by 190 miles. Later, a second burn of the SPS for 17 seconds placed the docked vehicles into a lunar orbit of 62 by 70.5 miles, which was calculated to change the orbit of the CSM piloted alone by Collins, because of lunar-gravity perturbations, to the nominal 69 miles required for subsequent LM rendezvous and docking after completion of the lunar landing. Before this second SPS firing, another TV transmission was made, this time of the surface of the Moon. On July 20, Armstrong and

Aldrin entered the LM again, made a final check, and at 100 hours 12 minutes into the flight, the Eagle undocked and separated from the Columbia for visual inspection. At 101 hours 36 minutes, when the LM was behind the Moon on its 13th orbit, the LMDE was fired for 30 seconds to provide retrograde thrust and commence descent orbit insertion, changing to an orbit of 9 by 67 miles, on a trajectory that was virtually identical to that flown by Apollo X. At 102 hours 33 minutes, after the Columbia and Eagle had reappeared from behind the Moon and when the LM was about 300 miles uprange, powered descent initiation was performed, with the LMDE firing for 756.3 seconds. After eight minutes LM was at "high gate," about 26,000 feet above the surface and about five miles from the landing site. The descent engine continued providing braking thrust (756.3 seconds) until, at about 102 hours 45 minutes into the mission, and partially piloted manually by Armstrong, the Eagle landed in the Sea of Tranquility on July 20, 1969, in Site 2, at 0°41′15″N. Lat. and 23°26′E. Long., according to NASA MSC. This was about four miles down range from the predicted touchdown point; occurred almost one-and-half minutes earlier than scheduled; and included a powered descent that ran a mere nominal 40 seconds longer than preflight planning, due to translation maneuvers to avoid a crater during the final phase of landing. The flight plan called for EVA to begin after a four-hour rest period, but it was advanced to begin as soon as possible. Nonetheless, it was almost four hours later that Neil Armstrong emerged from the Eagle, deployed the TV camera for the transmission of the event to Earth, and at about 109 hours 42 minutes from launch, Armstrong stepped on to the Moon. About 20 minutes later, Aldrin followed him. The camera was then positioned on a tripod about 30 feet from the LM. A half-hour later, President Nixon spoke by telephone link with the astronauts. During the EVA in which they both ranged up to 300 feet from the Eagle, Aldrin deployed the EASEP experiments, and Armstrong and Aldrin gathered and verbally reported on the lunar surface samples. After Aldrin had spent one hour and 33 minutes on the surface he re-entered the LM, followed 41 minutes later by Armstrong. The entire lunar EVA phase consumed over two-and-a-half hours, ending at 111 hours 39 minutes into the mission. After a rest period which included seven hours of sleep, and 21 hours and 36 minutes after the LM landed, the ascent stage engine was fired at 124 hours 22 minutes. It was shut down 435 seconds later when Eagle had reached an initial orbit of 11 by 55 miles above the Moon, when the Columbia with Collins was on its 25th revolution. As the ascent stage reached apolune at 125 hours 19 minutes, the RCS was fired so as to nearly circularize Eagle's orbit at about 56 miles, some 13 miles below and slightly behind Columbia. Subsequent firings of the LM RCS changed the orbit to 57 by 72 miles. Docking with the Columbia occurred on the CSM's 27th revolution at 128 hours three minutes into the mission, and Armstrong and Aldrin rejoined Collins in the CSM. Four hours later the LM was jettisoned and remained in lunar orbit. Trans-Earth injection of the CSM began on July 21 as the SPS was fired for two-and-half minutes when the Columbia was behind the Moon, in its 59th hour of lunar orbit. Following this, the astronauts slept for about 10 hours. A 11.2-second firing of the SPS accomplished the only mid-course correction required on the return flight; it was made on July 22, at about 150 hours 30 minutes into the mission. Two more television transmissions were made during the trans-Earth coast. Forty-four hours after leaving lunar orbit,

re-entry procedures were initiated July 24; the SM was separated from the CM which was re-oriented to a heat-shield-forward position; parachute deployment was made at 195 hours 13 minutes, and after a flight of 195 hours 18 minutes 35 seconds (barely 36 minutes longer than planned), Apollo XI splashed down in the Pacific Ocean 13 miles from the recovery ship USS Hornet. Because of bad weather in the target area, the landing point had been changed some 250 miles, so that Apollo XI landed 169°9′W. Long., 13°19′N. Lat. on July 24, 1969.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell (NR), CM and SM spacecraft prime contractor; SPS, Aerojet-General, principal and subcontractors; AVCO, ablative heat shield; Collins, communication and data subsystems; Garrett, environmental control system; Grumman, LM spacecraft prime contractor; PGNS, General Motors (manufacturing), MIT (technical management), principal and subcontractors; NR, ascent engine; RCA, communication subsystem and radar and control electronics, TRW, descent engine and abort guidance system; Hamilton-Standard, astronauts' portable life support systems; ILC Industries, space suits; Bendix, Early Apollo Scientific Experiments Packages; IBM, IU prime contractor; Boeing, Apollo-Saturn V technical integration and evaluation; GE, Apollo checkout equipment, related engineering design, quality management, and engineering support; TRW, mission trajectory control and spacecraft system analysis; NASA Marshall Space Flight Center, launch vehicle management; Boeing, first stage prime contractor; NR, second stage; McDonnell Douglas, third stage; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, Manned Space Flight Network management.

Key Spacecraft Personnel		Affiliation
Apollo XI – Command and Service Module		
PM	S. C. Phillies	NASA Headquarters
Apollo XI – Lunar Excursion Module		
PM	W. F. Eichelman	NASA-JSC
MG	F. I. Roberson	NASA Headquarters
SC	J. B. Hanley	NASA Headquarters
PS	None assigned	

Experiment	Experiment Personnel	Affiliation
Photos 70, 16 + 35 mm	PI Mapping Sciences Lab	NASA-JSC
Window Meteoroid Detector	PI B. G. Cour-Palais	NASA-JSC
	OI M. L. Brown	Lockheed Electronics
	OI D. S. McKay	NASA-JSC
Geologic Samples	PI E. M. Shoemaker	California Institute of Technology
Solar Wind Composition	PI J. Geiss	University of Berne
Seismograph, EASEP	PI G. V. Latham	University of Texas, Galveston
Laser Reflector	PI C. O. Alley	University of Maryland
Dust Detector	PI B. J. O'Brien	Department of Environmental Protection
	OI J. R. Bates	NASA-JSC
Soil Mechanics	PI J. K. Mitchell	University of California, Berkeley



President Richard M. Nixon greets the Apollo XI astronauts, inside their Mobile Quarantine Facility, aboard the USS Hornet.

INTELSAT III F-5

Launch Vehicle – Long Tank Thrust-Augmented (LTTA) Delta: modified Thor liquid-fueled first stage main engines yielding 172,000 pounds of thrust, augmented by three strap-on solid-propellant Castor II rockets, for a total first-stage thrust of 328,000 pounds (LTTA Delta had the same thrust as the earlier Thrust-Augmented Improved Delta version, but featured a longer burn time than the TAID); 7800-pound-thrust liquid-fueled second stage; up-rated third stage consisting of 10,000-pound-thrust TE-364 solid-propellant engine. Height 106.2 feet.

Spacecraft Description – Identical with previous Intelsat III spacecraft: magnesium cylinder 41 inches tall and 56 inches in diameter; exterior covered with solar cells. Aft and forward surfaces were enclosed except for slight extensions of the apogee motor skirt aft, and mechanically despun communication antenna, shaped like an inverted cone with its base cut at 45° extending 33.6 inches forward. Overall height, 78 inches. Around the nose of the communication antenna where it mated with the main body was mounted a doughnut-shaped omnidirectional telemetry and command antenna. Two axial thrusters were mounted aft; two radial thrusters mounted on the side; and Earth and sun sensors were side-mounted. Supportive subsystem equipment was mounted inside on a circular aluminum honeycomb platform. Spin stabilization at 90 rpm was provided. Weight was a nominal 322 pounds in orbit.

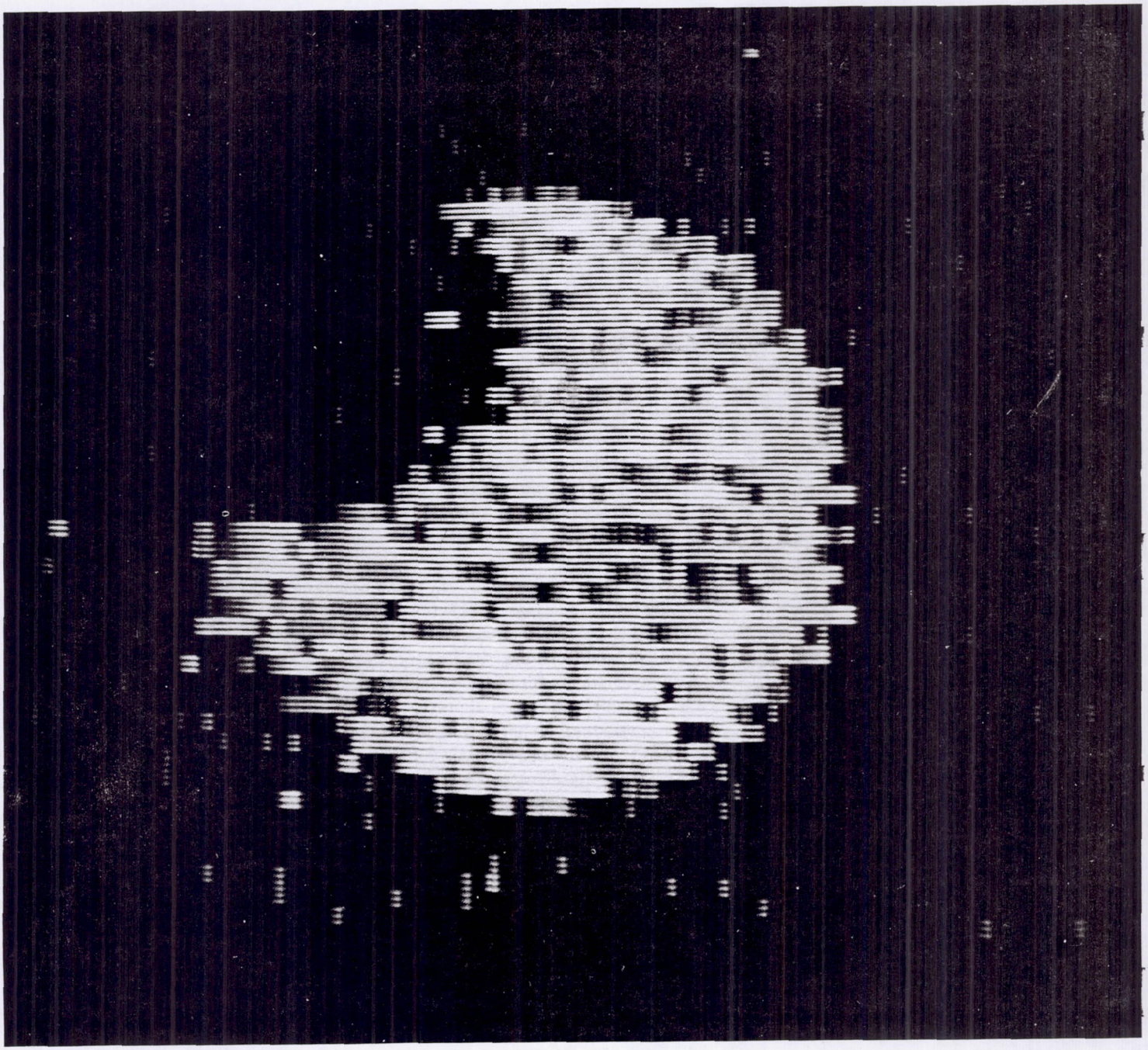
Project Objectives – This was to be a fourth increment to the first globally operational commercial communication-satellite system. Spacecraft III F-5 was to be placed over the Atlantic Ocean, to add service to the system by supplementing 3B in this heavy-traffic region.

Spacecraft Payload – The communication subsystem utilized a mechanically despun directional antenna and dual transponders to receive at 5930 to 6420 mHz, and transmit at 3695 to 4195 mHz. The satellite had a design capacity of 1200 circuits, capable of carrying up to four TV programs simultaneously. A five-year-lifetime electrical power system was to generate 130 watts from 10,720 solar cells; the system also had a rechargeable 20-cell nickel-cadmium battery for extended operation when the satellite was in the Earth's shadow. The design included a solid-propellant 3140-pound-thrust apogee motor providing a 6060-fps velocity increment for injecting the satellite into synchronous orbit. Attitude control and stationkeeping came from two nitrogen-pressurized monopropellant hydrazine-fueled propulsion systems, each system employing a pair of tanks to supply one radial and one axial thruster.

Project Results – Intelsat III F-5 was launched from Cape Kennedy on July 26, 1969. The launch was normal up to second-stage burnout, according to telemetry. But due to third-stage malfunction, the satellite was launched into an initial elliptical orbit of 167 by 3355 miles, from which recovery for geostationary positioning was impossible. The failure of the telemetry-less third stage to inject into a proper orbit was attributed to a possible rupture of the third-stage motor casing or nozzle.

Major Participants – Comsat Corp., spacecraft management; TRW, spacecraft prime contractor; NASA Goddard Space Flight Center, launch vehicle management; McDonnell Douglas, launch vehicle prime contractor.

Á solar eclipse recorded August 9, 1969 by OSO VI as it collected data on the sun's X-rays, gamma rays,and radio emissions.



1969

OSO VI

Launch Vehicle – Long Tank Thrust-Augmented (LTTA) Delta N (two stages): modified Thor first stage with liquid-fueled main engines yielding 172,000 pounds of thrust, augmented by three strap-on solid-propellant Castor II rockets, for a total first stage thrust of 328,000 pounds; standard 7800-pound-thrust liquid-propellant second stage. Height 81 feet.

Spacecraft Description – OSO VI: same basic two-stage design as previous OSO's; overall height, 37 inches. Spinning wheel-like base, a nine-sided aluminum drum 44 inches in diameter, revolving at 30-40 rpm, allowed five experiments housed in compartments in the base section to scan the sun every two seconds. Pitch-control system maintained the base spin axis perpendicular to the sun while overall spacecraft was pointed with an accuracy of one minute-of-arc. Base also held power, command spin-control, and communication subsystems. Overall diameter increased to 92 inches when three spin-control booms (arms) were extended for stabilization; nitrogen gas stored in spheres at end of booms were part of controls for spin rate. Upper "sail" portion, fan-shaped and 23 inches high, contained directionalized instrumentation and solar cell panels, and faced the sun during daytime. Magnetic bias coil augmented pitch control, saved gas consumption. Design lifetime, six months. Weight 640 pounds.

A piggyback experiment, called the Package Attitude Control (PAC) satellite, which comprised a flight test of a semi-active gravity-gradient stabilization technique, was launched with OSO VI. The space vehicle for this orbital test of a semi-active gravity-gradient stabilization (SAGS) system was attached to the expended second stage of the Delta N vehicle, which was 16 feet long and 4.7 feet in diameter; both were designed to orbit together. The spacecraft provided power, telemetry, and command support to the SAGS experiment within the satellite segment. Weight of PAC plus stage, 265 pounds.

Project Objective – OSO VI: continuation of the OSO program of study of the sun's X-rays, gamma rays, and radio emissions to better understand the sun's structure; to obtain sharper determination of the solar influence on the Earth; and to obtain baselines for studying other more distant suns. The primary objective for OSO VI was the acquisition of high spectral-resolution data, within the range of one to 1250 angstroms. Several experiments were extensions of studies begun with earlier OSO's; two experiments were furnished by England and Italy for OSO VI. Concentration was given to studying solar flares, serving as one source for early warning to astronauts on manned space flights and EVA missions. Eventual goals, using data combined with that obtained from other spacecraft programs, was to permit solar eruption predictions to provide advance warnings of dangers to deep space or manned lunar explorations, and to permit more qualified study of distant suns. PAC 1: Mission objective of this first PAC flight was the flight-test of SAGS, a long life, low-powered, three-axis Earth-stabilized control system.

Spacecraft Payloads – OSO VI carried seven experiments weighing 227 pounds. Two directionalized experiments were located in the sail portion. The spacecraft's operational support subsystems and the remaining five experiments were mounted in compartments in the rotating base, scanning the

solar disk every two seconds when the satellite was illuminated by the sun. The experiments were solar ultraviolet spectrometer-spectroheliograph to obtain data in the region of 300 to 1300 Å, and the spatial distribution of selected UV wavelengths; a spectral, burst, and mapping spectrometer to measure solar X-rays in the region of 0.13 to 27 Å, some measurements with high spectral resolution in the 0.6 to 25 Å band; a polarimeter to determine the brightness, polarization, and ellipticity of zodiacal light; spectrometers to observe solar X-ray emission lines in the 16 to 40 Å spectral range; a telescope to determine the high energy neutron flux in the 20 to 130 mev energy range; an X-ray telescope to observe solar and cosmic X-rays in the 20 to 200 kev range and to measure the albedo in this range; and a solar ultraviolet polychrometer to study the Me-I (584 Å), He-II (304 Å), O-II (833 Å), O-IV (790 Å) and N-III (922 Å) resonance line radiations. A first-time capability in the OSO program was precision offset raster pointing of the satellite's sail-mounted experiments. Whereas three previous OSO's could only point to the sun's center or scan across the solar disk, OSO VI could offset point to any one of 16,384 points on a 128-by-128-point grid, and perform a 7-by-7.5 arc-minute raster in azimuth and elevation respectively, about any of these points. The sail portion essentially was capable of four pointing modes: a pointed or oriented mode with the experiments aimed at the center of the sun within one arc-minute; the offset-point mode in which the spacecraft was pointed to any one of the intersections on the 128-by-128-point grid pattern that was larger than the diameter of the solar disk; the large raster scan in which the sail scanned the solar disk and corona within 46 arc-minutes both in azimuth and elevation; and the new offset scan described above in which the sail locks on to any one of the 16,384 points. Scanning was initiated by ground command and was terminated automatically by a "night" signal. Power supply of 38 watts was provided by four square feet of 2016 n-on-p solar cells. PAC 1: The 55-pound payload comprised the SAGS attitude control and sensing assembly, a solar cell power system attached to the body, a communication and data handling system, and a thermal control system. Instead of using propellants, momentum control was provided by gravity torques achieved by utilizing the pendulum effect of the stage to point the long axis toward the Earth's center. The SAGS consisted of a reaction wheel scanner, gimballing mechanism with passive damping and control electronics, and provided three-axis stabilization for the combined satellite and Delta stage.

Project Results – OSO VI and PAC 1 were launched from Cape Kennedy on August 9, 1969 into nearly circular orbits. OSO VI's initial orbit was 305 by 344 miles, at an inclination of 32.9 degrees. PAC 1 was injected into an orbit of 269 by 299 miles at the same inclination. All experiments were functioning normally.

Major Participants – NASA Goddard Space Flight Center (GSFC), OSO VI spacecraft, launch vehicle, and experiment management; Ball Bros. Research Corp., spacecraft prime contractor; Harvard College, Rutgers Univ., Univ. of New Mexico, Italian Univ. of Bologna, Univ. College of London, U.S. Naval Research Lab., and Los Alamos Scientific Labs., experimenters; GSFC, PAC 1 spacecraft and experiment management, prime contractor, and experimenter; McDonnell Douglas, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	J.M. Thole	NASA-GSFC
PS	S.P. Maran	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Spectro Heliometer, 300-1400A	PI	L. Goldberg	Harvard College Observatory
	OI	E.M. Reeves	Harvard College Observatory
	OI	W.H. Parkinson	Harvard College Observatory
Solar X-Ray, Spectrometer + Scintillator	PI	R.W. Kreplin	US Naval Research Laboratory
	OI	T.A. Chubb	US Naval Research Laboratory
	OI	J.F. Meekins	US Naval Research Laboratory
	OI	H.D. Friedman	US Naval Research Laboratory
Zodiacal Light, Int. + Polar	OI	A.L. Rouy	Rutgers University
	PI	B. Carroll	Rutgers University
	OI	L.H. Aller	University of California, Los Angeles
Solar X-Rays, 16-40A	PI	H.V. Argo	Los Alamos Science Laboratories
	OI	B.I. Henke	Los Alamos Science Laboratories
	OI	J.A. Bergey	Los Alamos Science Laboratories
	OI	W.D. Evans	Los Alamos Science Laboratories
X-Ray Solar + Albedo, 20-200kV	PI	D. Brini	CNR, Space Plasma Laboratory
	OI	M. Galli	University of Bologna
	OI	D.D. Cattani	University of Bologna
	OI	F. Evangelisti	University of Bologna
	OI	F. Fuligni	University of Bologna
	OI	D. Moretti	University of Bologna
Helium Resonance Radiometer 584 + 304A	PI	R.L.F. Boyd	University College London
	OI	B.E. Woodgate	NASA-GSFC
Neutron Flux, 20-130MeV	PI	C.P. Leavitt	University of New Mexico

Launch Vehicle – Atlas Centaur: 395,340-pound-thrust Atlas first stage including two 670-pound-thrust vernier engines for roll control; 30,000-pound-thrust Centaur second stage. First stage guided by preprogrammed autopilot; second stage inertially guided. Height (including shroud) 118 feet.

Spacecraft Description – Similar to previous ATS: main body was 72 inches long, and total length: 132 inches from top of omnidirectional antenna to aft end of apogee motor; the 60-inch-diameter cylinder was covered with 22,000 negative-on-positive silicon solar cells, except for a wide area in a band around the midsection, which contained externally mounted or viewing experiment payloads. Appendages included four motor-deployed 124-foot-long gravity-gradient booms (totally spanning 253 feet), forming an X with the satellite at its center; two 45-foot booms protruding diagonally through the spacecraft to dampen vertical motion; a fan-like array of whip antennas for telemetry and command extending from the rim of the forward end; and 12 spiral antennas for L-band transmissions. A 6250-pound-thrust apogee motor extended from the aft end, to be ejected after firing the spacecraft into synchronous orbit. Weight (after apogee motor burnout and jettison) 954 pounds.

Project Objectives – Primary objective was the evaluation of gravity-gradient stabilization for Earth-pointing synchronous satellites. Additional prime objective was the assessment of the use of L-band communications for aircraft traffic control, communication, navigation. Other objectives included a first-time flight test of the use of the millimeter wave band for satellite telemetry and communication links to Earth; use of this band could open up more frequencies for such purposes and, with greater satellite power, could require less complex Earth stations. Remaining objectives for ATS V included tests of simultaneous multi-station access for communication in the microwave C-band for voice, TV, telegraph, and digital data, and a series of engineering and scientific experiments.

Spacecraft Payload – Heaviest payload and largest number (13) of experiments yet carried by an ATS. Four gravity-gradient booms were each made of two-inch-wide aluminum-plated perforated beryllium-copper strips, about two pounds each and coiled like a carpenter's tape on motor-driven drums; they were to expand to form individual one-half-inch-diameter booms with eight-pound weights attached about four inches from the tips. The system was to stabilize the satellite in three axes within plus-or-minus six degrees in both pitch and roll and eleven degrees in yaw. The booms could be scissored from 13 to 29 degrees off local vertical. A standard 525-line TV camera was positioned on the spacecraft's middle experiment shelf to monitor the amount of bending in the four gravity-gradient booms. Nine-inch diameter targets to enchance motion coverage for the TV camera were affixed to the tips of the four booms. To augment these booms, two larger-diameter 45-foot-long beryllium-copper booms were extended in diametrically opposite directions through the vehicle, and were attached to a passive damper. Two passive damping systems were on board for efficiency evaluations; an eddy-current damper and a hysteresis damper. Attitude sensing to within one degree of local vertical was to be performed by a

solar-aspect sensor, an infrared Earth sensor, a polarized antenna, and the TV camera. There were six reaction control subsystems: a cold-gas nitrogen assembly for spin-up; a hydrazine assembly for inclination and eccentricity adjustments and initial stationkeeping; a microthrusting resistojet (about 50 micropounds of thrust) and a cesium-contact ion engine (from five to 20 micropounds) for stationkeeping during gravity stabilization; two subliming solid-jet rockets producing a thrust of 600 micropounds to invert the satellite after in-flight attitude maneuver experiments; and an active nutation control system to serve during transfer-orbital flight. An experiment in C-band communications was to function at four to six gigahertz for simultaneous receiving and transmitting (capacity of either 1200 one-way or 600 two-way circuits) between the satellite and multiple ground terminals; the C-band transponder was to serve as a multiplex telephone relay repeater. An L-band experiment was to operate in the 1550 to 1650 mHz range. A 40-pound millimeter wave unit was to provide a first-time space test of propagation characteristics in the range above 10 gHz to just below the infrared spectrum (10^{15} Hz). This unit had dual antennas for receiving at 31 gHz and transmitting at 15 gHz. A near-Earth environmental measurements experiment package contained six instruments. A tridirectional particle detector was to measure protons with energies between 30 and 250 kev and electrons between 30 and 300 kev, along two axes of the satellite. A unidirectional particle experiment was to study auroral particle fluxes at geostationary altitude, measuring electrons within the range of 0.5 to 50 kev, and protons at 1 kev, 5 kev, 20 kev, 60 kev, and 100 kev. A bidirectional particle experiment was to map the distribution of 60 kv to 60 kev electrons and protons on a constant line of force, and determine the nature of the properties of acceleration occurring within the magnetosphere. An omnidirectional particle experiment was to measure electrons in 12 discrete energy ranges between 0.5 and 5 mev and the flux of solar cosmic rays between 12 and 24 mev. Solar radio burst effects measurements at 32 discrete frequencies between 50 kHz and four mHz were to be conducted using the four 124-foot booms as receiving antennas. The electric field in the magnetosphere was to be measured by utilizing the same gravity-gradient booms as long cylindrical Langmuir probes. Radiation damage experiments were to be conducted with the solar cells, to investigate the effects of the synchronous altitude environment on various solar cell designs. The apogee injection motor was the same basic design as used on ATS I, III, and IV, providing 6250 pounds of thrust.

Project Results – ATS V was launched from Cape Kennedy on August 12, 1969 into a near-perfect trajectory for subsequent insertion into synchronous orbit. Shortly after separation, when the spacecraft entered its elliptical transfer orbit, it began to wobble on its spin axis. The attitude control hydrazine jets had to fire 15 times faster than normal to reduce the wobble to required limits. As a result, the apogee insertion motor was commanded to fire when the satellite reached its first apogee over the Bay of Bengal, instead of on the second, as planned. Ground control anticipated ejecting the motor casing 90 seconds later, before the spacecraft was to go into a flat spin. However, it went into the flat spin around the yaw axis about 20 seconds after apogee-motor firing, when the nutation damping system could not dissipate the greater-than-expected energy, and it became impossible to

eject the motor without its striking the satellite, possibly causing the casing to strike the hydrazine tanks or tubing. The satellite was allowed to drift toward its planned geostationary location at the Equator, about 1100 miles west of Quito, Ecuador, which took about 20 days to achieve. The intended second-apogee firing would have permitted placing the satellite in that location more accurately, and within 11 hours after launch. The motor and casing were successfully jettisoned on September 5, 1969. Although the satellite was upright, it was wrongly spinning counterclockwise; hence the gravity-gradient experiment booms could not be deployed. Nine of the other 13 experiments were returning useful data. Because of the spin, it was not possible to obtain data from the resistojet, ion engine, solar cell voltage monitor, and heat pipe solar panel experiments.

Major Participants – NASA Goddard Space Flight Center (GSFC), spacecraft management; Hughes, spacecraft prime contractor; General Electric, Westinghouse, Univ. of Calif., Berkeley and San Diego, Lockheed, and GSFC, experimenters; JPL, apogee motor; NASA Lewis Research Center, launch vehicle management; General Dynamics, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	Don Fordyce	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
24HR Gravity Gradient Experiment	PM	C.M. Mackenzie	NASA-GSFC
	MG	W.M. Lew, Jr.	NASA Headquarters
Electric Fields, DC-10KHZ	PI	T.L. Aggson	NASA-GSFC
Solar Radio Noise Bursts	PI	R.G. Stone	NASA-GSFC
Energy Particle (E/.5-5, P/12-24)	PI	C.F. McIlwain	University of California, San Diego
Energy Particle E + P GT 5keV	PI	F.S. Mozer	University of California, Berkeley
Energy Particle E + P 5-500keV	PI	R.A. Sharp	Lockheed, Palo Alto
	OI	J.B. Reagan	Lockheed, Palo Alto
Millimeter Wave Propagation	PI	L.J. Ippolito	NASA-GSFC
Communication Microwave Transponder	PI	Unknown	Unknown
Communication L-Band Transponder	PI	Unknown	Unknown
Gravity Gradient Stabilization	PI	Unknown	Unknown
Ion Engine Thrustor	PI	Unknown	Unknown

Experiment	Experiment Personnel	Affiliation
Low Energy Proton Electrons	PI C.E. McIlwain	University of California, San Diego
	OI R.W. Fillius	University of California, San Diego
	OI S.E. Deforest	University of California, San Diego
Beacon Experiment	OI O.K. Garriott	NASA-JSC
	PI A.V. Darosa	Stanford University
Magnetic Field Monitor	PI M. Sugiura	NASA-GSFC
	OI R.A. Langel	NASA-GSFC

PIONEER E, TETR C

Launch Vehicle – Long Tank Thrust-Augmented (LTTA) Delta: same as for Intelsat 3E, above, except for use of standard 5740-pound-thrust FW-4 solid-propellant third stage. Height 106.2 feet.

Spacecraft Description – Pioneer E: same basic configuration as Pioneers VI, VII, VIII, and IX – cylinder 37 inches in diameter and 35 inches high, with sides covered by solar cells except for narrow circular band around the middle containing apertures for four experiments and five sun sensors. Three 64-inch booms were to be deployed at 120-degree intervals from the midsection band. A 52-inch command and telemetry antenna extended from the center of one end; an experiment antenna was mounted on the rim of the other end. Spacecraft structure was primarily aluminum, spin stabilized at 60 rpm. Weight 148 pounds. TETR C: similar to its predecessors – octahedron 12 inches on a side, with solar cells covering each of the eight sides. Top apex supported an S-band antenna with mast; VHF transmitter antenna sections extended from two opposing apexes in the center plane; the launch and ejection fitting was mounted at the bottom apex. Also located near the bottom apex was the VHF command telemetry antenna section. Weight 45 pounds.

Project Objectives – Pioneer E would have been called Pioneer X if successfully orbited. Its experiments were to make ultraprecise measurements of fine-scale magnetic disturbances in interplanetary space, as well as to measure cosmic rays, solar plasmas, cosmic dust, electric fields, and electron density. The data was to be used in conjunction with similar data from previous Pioneers and other satellites, during the peak of the 11-year period of solar activity. The studies were to include flux, energy spectrum, and directional characteristics of positive ion and electron components of the solar wind, determining the energy and number of these particles. Radio propagation experiments were also to be conducted, to determine time and space variations of the integrated electron density between Earth and the spacecraft. Pioneer E was to be placed in solar orbit along the path of the Earth's orbit, so as to pass inside and outside it, alternately speeding up and slowing down relative to Earth. This was to maintain the spacecraft within 10 million miles of Earth during its design lifetime of from six months to two and one-half years. TETR C was to be a third orbiting target for a series of exercises by ground stations and shipboard terminals of NASA's Manned Space Flight Network. It was to be used for testing techniques of acquisition, range-rate determination, telemetry simulation, voice communication, and handover of control from one station to the next, as exercises for manned spaceflight missions to follow.

Spacecraft Payload – Pioneer E carried seven experiment packages. A three-axis magnetometer was mounted on one of the radial booms, to continuously measure the strength and direction of interplanetary magnetic field in three axes. A quadrispherical plasma analyzer was to measure the direction, quantities, energies, and temperatures of particles in the solar wind. A cosmic ray anisotropy detector was to determine arrival direction, mass, and energy (speed) of solar and galactic cosmic ray particles. A cosmic ray telescope was to measure numbers, energy, direction, charge, and distribution through-

out interplanetary space of atomic nuclei, ranging in size from one million to one billion electron volts; the equipment comprised three solid-state lithium-drift detectors, two solid-state surface-barrier detectors, one detector with a synthetic sapphire window to a photomultiplier, and one with a plastic guard cap monitored by photomultipliers. A cosmic dust detector was to determine the velocity, mass, and flux of minute particles measuring from 50 millionths to less than one trillionth of a gram and travelling at speeds up to 900,000 mph. The electric field experiment was to detect components of low-frequency radio waves, and waves created by variations in the solar wind density. A radio propagation experiment was to determine the total electron content between Pioneer E and Earth. A celestial mechanics experiment, to be conducted from the ground using precision spacecraft radar tracking data gathered by the NASA Deep Space Network (DSN), was to better determine AU distances, the shape and orientation of the planetary orbits, and the general theory of relativity. The spacecraft's two-way S-band communication system was to function at about 2200 mHz, and consisted of a transmitter, receivers, a command decoder, a command distribution network and a digital telemetry system for transmitting spacecraft and experiment data to the ground. Data rates could be varied to achieve maximum efficiency at varying distances, and ranged from 8, to 16, 64, 256, and 512 bits per second. Attitude control was to be achieved by utilizing the gyroscopic effect of the spinning (60 rpm) spacecraft, modified by nitrogen gas jets at the end of one of the radial booms; thrusts were to be timed by a sun sensor; wobbling rotation was to be eliminated by utilizing the flexibility of the three radial booms and a damper that consisted of two small balls in two cylinders at the end of a boom. Pioneer E, like earlier Pioneers, also was to be maintained with its spin axis perpendicular both to the sun-spacecraft line and the Earth-spacecraft line, so that solar cells would be efficiently illuminated and the narrow-beam antenna could focus on the Earth. Sixty watts of power were to be supplied by 10,368 silicon n-on-p solar cells. Passive heat control was to be achieved by exterior heat-reflective coatings actively controlled by 20 spring-actuated louvers at the spacecraft base. TETR C carried an S-band transponder, to receive at 2101.8 mHz and transmit at 2282.5 mHz. Signals were to include ranging telemetry, voice, and biomedical information to simulate data that would ordinarily emanate from Apollo spacecraft. Electrical power was to be furnished by rechargeable battery and some 900 solar cells. The TETR was to be magnetically stabilized.

Project Results – Pioneer E and TETR C were launched from Cape Kennedy on August 27, 1969. The launch appeared nominal until just seconds before first-stage burnout, when the vehicle suffered a loss of hydraulic pressure, throwing it off course. At 8 minutes 3 seconds into powered flight, as the vehicle's attitude dipped about 90 percent off angle, the range officer destroyed the vehicle.

Major Participants – NASA Ames Research Center (ARC), Pioneer E spacecraft management; NASA Goddard Space Flight Center (GSFC), TETR C spacecraft management; TRW, Pioneer and TETR, spacecraft prime contractor; ARC, GSFC, Southwest Center for Advanced Study, Univ. of Minnesota and Stanford, and TRW, experimenters; McDonnell Douglas, launch vehicle prime contractor.

BOREAS (ESRO 1B)

Launch Vehicle – Four-stage solid-propellant Scout: 100,944-pounds-thrust Algol IIB first stage; 60,764-pound-thrust Castor II second stage; 20,942-pound-thrust Antares II third stage; and 5746-pound-thrust FW-4S fourth stage. First three stages were inertially guided, fourth stage spin stabilized. Height 73 feet.

Spacecraft Description – Identical with Aurorae (ESRO 1A): cylindical body 60 inches high and 30 inches in diameter with shallow truncated cones at each end, and surface covered by 6990 solar cells except for a band around the middle. Three experiment booms extended out from the main body: one from the top, about 20 inches, along the spin axis; and two others each about 39 inches long, from the bottom and perpendicular to the spin axis. Four telemetry antennas extended from the top rim of the satellite. Weight 176 pounds.

Project Objectives – Fourth European-designed and built satellite launched in a cooperative program between ESRO and NASA, which provided the launch vehicle and facilities. The mission was a repeat of the earlier Aurorae. Boreas carried eight experiment packages (from four countries) that were identical with those on Aurorae, except for minor technical improvements. Scientific measurements were to be concentrated over Northern Europe to correlate data from ground-based sounding rockets launched from the Kiruna range in Sweden. Measurements to be taken included energies and pitch angles of particles impinging on the polar ionosphere during magnetic storms and quiet periods. Effects to be studied included the production of visible light during auroral events, and the changes in electron and ion densities and temperature distributions.

Spacecraft Payload – The eight experiment packages were to measure: absolute auroral luminosity; electron density and temperature; positive ion composition and temperature; high energy electrons and protons; low energy electron and proton precipitation on the northern auroral zone; medium energy protons; and the integral particle flux of protons and electrons. Boreas was initially spin-stabilized at about 148 rpm, then despun to one rpm by a yo-yo mechanism housed in a narrow band around the middle. A magnetic system which interacted with the Earth's magnetic field provided additional despin momentum, and final phase stabilization was provided by a passive system consisting of two permanent magnets. The solar panels generated 23 watts of power, augmented by a 16-cell battery. A low speed PCM telemetry system, which provided continuous data transmission at 320 bits per second, had a low-powered transmitter operating at 0.2 watt, at 136.2 mHz. A high speed PCM telemetry system provided real-time and stored data transmissions through a higher powered transmitter operating at 1.2 watts, at 136.9 mHz. A single tape recorder on board had a three-minute playback capacity.

Project Results – Boreas was launched from Vandenberg AFB in California on October 1, 1969 into an improper orbit of 189.5 by 243.6 miles, versus the planned orbit of 248.5 by 270.3 miles. The lower orbit was due to booster malfunction. The satellite became operational on October 21. The eight experiments operated satisfactorily, although the tape recorder be-

came unusable on the 87th orbit and was switched off. To compensate, real-time data was read out by as many ground stations as possible. Correlation of data with Aurorae was good. In its almost 53 days in orbit, Boreas transmitted more than 3400 minutes of real-time data. After 835 orbits, on November 23, 1969, due to orbital degradation from atmospheric drag in its low orbit, Boreas decayed in the atmosphere over the Canary Islands.

Major Participants – European Space Research Organization, spacecraft management; European Space Technology Center (ESTEC), spacecraft technical director; Laboratoire Central de Telecommunications, spacecraft prime contractor; Norwegian Institute of Cosmic Physics, Oslo; University College (London) Mullard Space Research Laboratory, Dorking, England; Radio and Space Research Station, Slough, England; Kiruna Geophysical Observatory, Sweden; Danish Space Research Institute, Lyngby, Denmark; and the Norwegian Defence Research Establishment, Kjeller, Norway, experimenters; NASA Goddard Space Flight Center, U.S. project coordinator; NASA Langley Research Center, launch vehicle management; LTV, launch vehicle prime contractor.

GERMAN RESEARCH SATELLITE A AZUR

Launch Vehicle – Four-stage solid propellant Scout. Same as for Boreas (ESRO IB).

Spacecraft Description – Main portion of the Azur satellite was a cylinder 30 inches in diameter, with a truncated cone-shaped forward end, and 44.4 inches high. Four antennas extended from the flat circular aft end, together with a deployable 32.4-inch magnetometer; total height is 76.8 inches. Central structural support was provided by cylindrical tube, structural cross members, and a circular equipment platform, attached to the central tube near its forward third. The tube, composed of plastic reinforced by fibrous glass, served both as the attaching mount to the launch vehicle's fourth stage, and the housing for the magnetometer that was deployed after separation. More than 5000 solar cells covered the bottom and the circumference of the satellite. The equipment platform and solar panels were fabricated of honeycomb materials. Weight 157 pounds.

Project Objectives – The experimental objectives included: investigations of periodic variations in the intensity and energy spectrum of charged particles in the Earth's radiation belt; investigation of the periodic and spatial characteristics of solar particle flows that occur in conjunction with polar aurora, and accompanying variations in the Earth's magnetosphere; and investigation of the phenomenon of solar particle radiation reaching Earth. Special emphasis was placed on measuring the intensity and distribution of protons and electrons in terms of time. The data was to be gathered in the cooperative program between West Germany and the U.S., to be published by Germany, and subsequently made available in accordance with a data-exchange program to augment data from studies conducted through the U.S. Explorer and OGO satellites.

Payload Description – Azur was initially stabilized by a 178-rpm spin up from the booster's fourth stage; after separation, spin was reduced to about zero by a two-stage yo-yo system on the spacecraft's outer surface. Eight interior hysteresis damping rods provided further damping so that after about 10 days in orbit the satellite was automatically stabilized along the Earth's magnetic field by two elliptical bar magnets mounted near the center on the central tube structure. Temperature control is passive. Thirty-three watts of electrical power generated by the solar cells were expected to degrade to 27 watts after one year; a silver-cadmium battery provides back-up power. There were 70 telecommand channels, with data being transmitted over 35 analog and digital telemetry channels. Commands were received at 148.3 mHz, and data was transmitted by two PCM/FM transmitters operating at 136.6 and 136.7 mHz at about 0.5 watt. Real-time transmission was 1920 bits per second; a tape recorder had a recording speed of 96 bps and playback rate of 4800 bps. Data was transmitted in real-time; measurements were made only when the satellite was in the Earth's shadow. Azur carried seven scientific experiments: a flux gate magnetometer on a boom extending from the bottom of the satellite; two proton-alpha telescopes, each consisting of seven semiconductor surface-barrier detectors mounted one behind the other; a telescope consisting of two identical surface-barrier semiconductor detectors mounted one behind the other to measure low energy

protons and electrons in two energy ranges; and electron detector with four Geiger Mueller counters having very thin mica windows so that 40 kev electrons may be detected; a proton monitoring experiment with two Geiger Mueller counters with range cross sections mounted on top of the satellite; and the photometer experiment consisting of three units, each unit having a photomultiplier watching the optical intensity behind an interference filter, two photometers looking toward the Earth over the northern hemisphere, and the third looking away from the Earth to serve as a background reference. Auroral optical emissions in the 3914 Å and 2972 Å range were observed.

Project Results – Azur was launched on November 8, 1969 from Vandenberg AFB into an elliptical solar-synchronous polar orbit that initially measured 238.5 by 1954.6 miles, at an inclination of 102.9 degrees. The satellite stabilized after a few orbits, and all scientific equipment was switched on and tested for efficiency. Initial reports indicated Azur began its intended year-long orbital life by achieving expected data yields. Its orbit was initially to keep the satellite in the Earth's shadow regions over the northern hemisphere for a few months, and its orbital perigee over the northern hemisphere, to maximize data acquisition by ground stations.

Major Participants – West Germany's Gesellschaft fuer Weltraumforschung (GfW), Bonn, overall project management; Messerschmitt-Boelkow-Blohm GmbH, Munich, systems engineering, technical direction, and spacecraft prime contractor; AEG-Telefunken, Dornier System GmbH, and ERNO-Raumfahrttechnik, prime subcontractors; GfW, directing activities performed by stations both in Europe and by NASA's STADAN facilities, tracking control; Goddard Space Flight Center, NASA project management; NASA Langley Research Center, launch vehicle and facilities management.

Key Spacecraft Personnel		Affiliation
PM	A. Kutzer	Gesellschaft Fuer Weltraum Forschung
PM	A.L. Franta	NASA-GSFC
PS	E. Keppler	MPI-Aeronomy
PS	G.F. Pieper	NASA-GSFC
CO	A.W. Schardt	NASA-Headquarters
CO	R. Miller	NASA-Headquarters
CO	C.F. Rice	NASA-GSFC
CO	B.G. Narrow	NASA-GSFC
CO	D. Stewart	NASA-GSFC
CO	G.D. Repass	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
2 Flux-Gate Magnetometers, EI15	PI	G. Musmann	Braunschweig Technische Universitaet
P. + A. Tele. 1.4-100MeV, EI88	PI	D.K. Hovestadt	MPI-Extraterrestrial Physics
Proton-Tele. 0.2-20. MeV, EI92	PI	J. Moritz	University of Kiel
Proton-Electron Detector, EI93	PI	D.K. Hovestadt	MPI-Extraterrestrial Physics
Geiger-Mueller Electron Counters, EI95	PI	L. Rossberg	National Research Council of Canada
Geiger-Mueller Proton Counters, EI101	PI	E. Kirsch	MPI-Aeronomy
2 Auroral Photometers, EI102	PI	A. Rossbach	DFVLR

APOLLO XII

Launch Vehicle – Saturn V (AS 507), basically similar to AS 506 used for Apollo XI, with minor exceptions: Apollo XII's S-IC first stage generated 7.62 million pounds of thrust; S-II second stage generated up to 1.16 million pounds of thrust; S-IVB third stage, up to 207,256 pounds of thrust. Total height (also including the LES) was also 362.8 feet.

Spacecraft Description – Apollo XII was the heaviest Apollo spacecraft yet flown; 96,795 pounds. The spacecraft's module sections were basically similar to those of Apollo XI, with slight differences. The combined CM-SM, known as "Yankee Clipper" consisted of CM 108 which weighed 12,365 pounds, and SM 108 which weighed 51,105 pounds. The SLA stage weight was the same. "Intrepid," LM 6, had a descent stage that weighed 4875 pounds "dry" and 22,800 pounds with propellants; the ascent stage weighed 4760 and 10,525 pounds and the same way, respectively.

Project Objectives – The primary mission objectives of Apollo XII were the second manned lunar landing, an extensive series of lunar exploration tasks by the LM crew, as well as the deployment of the Apollo Lunar Surface Experiments Package (ALSEP), which was to be left on the Moon's surface to gather seismic and other scientific and engineering data over a long time, powered by a nuclear power source. Other objectives included selenological inspection, surveys, and samplings in the landing areas; development of techniques for a precision-landing capability; further evaluations of man's capability to work in the lunar environment, over a protracted period of time; deployment and retrieval of other scientific experiments; and photography of candidate exploration sites for future missions. The astronauts were also to retrieve portions of the Surveyor III spacecraft which had soft-landed on the Moon April 20, 1967, a short distance from the selected landing site of Apollo XII. The flight plan for Apollo XII was similar to that of Apollo XI, except Apollo XII was to fly a higher inclination to the lunar equator and leave the free-return trajectory after the second translunar midcourse correction scheduled en route to the Moon. This, the first non-free-return trajectory on an Apollo mission, was designed to allow a daylight launch, a translunar injection above the Pacific Ocean, a stretch out of the translunar coast to gain the desired landing site lighting at the time of LM descent, to conserve fuel, and to permit the Goldstone, California, tracking antenna to monitor the LM descent and landing. In addition, the Apollo XII flight plan called for using the LM ascent stage to provide a measured seismic stimulus for the ALSEP seismic experiment. After jettisoning the ascent stage following crew return to the CSM, a controlled burn of the remaining propellants in the empty ascent stage was to crash the stage into the Moon, to provide a measurable seismic shock impulse.

Spacecraft Payload – Apollo XII's payload and equipment were basically similar to those on Apollo XI, with the primary difference being the modification of the LM descent stage to accommodate the ALSEP payload. Additional changes included a second color TV camera for lunar surface transmissions; installation of four sun sensors on the SM to provide outside temperature readings during the flight to and from the Moon as the spacecraft slowly rotated to equalize temperature distribution; and a 500-mm

lens replacing the 60-mm lens for the camera equipment in the CM, to permit photographing objects on the lunar surface as small as six feet square, as the CM orbited 69 miles up. The all-Navy crew on Apollo XII were: spacecraft mission commander Charles Conrad, command module pilot Richard F. Gordon, and lunar module pilot Alan F. Bean. Conrad, a Navy Commander was 38; Gordon, also a Navy Commander, was 39; and Bean, a Lieutenant Commander, was 37. The ALSEP instrumentation included a lunar surface magnetometer (LSM), to measure the magnetic field at the lunar surface; a lunar ionosphere detector (LID), to study charged particles in the Moon's atmosphere; lunar atmosphere detector (LAD), to measure the density, temperature, and changes in the lunar atmosphere; a solar wind spectrometer (SWS), to measure the strength, velocity, and directions of electrons and protons from the Sun; a passive seismic experiment (PSE), to measure seismic activity of the Moon and obtain information on the properties of the lunar crust and interior; and a lunar dust collector. The ALSEP instrumentation was to be powered on the lunar surface by a 63-watt SNAP-27 radioisotope thermoelectric generator (RTG), 18 inches high, 16 inches in diameter around the circumference of the heat-radiating fins, and weighing 43.5 pounds including the fuel capsule. Other experiment packages included a solar wind composition experiment (SWCE), to collect gasses of the solar wind for return to Earth for analysis; and the second color TV camera, a B&W camera, and other photo camera equipment, which varied slightly from Apollo XI. A 70-mm Hasselblad electric still camera was stowed in the CSM for general photography. In the LM were two 70-mm Hasselblads with 60-mm lenses, a 16-mm motion picture camera with a 10-mm lens, and a 35-mm closeup stereo camera for selenological photos. Two 16-mm Maurer motion picture cameras were also flown in the CSM on Apollo XII. The S-158 experiment for lunar multispectral photography comprised an assembly of four side-by-side-mounted Hasselblads, each fitted with a different filter and type of film.

Project Results – Apollo XII was launched from Cape Kennedy on November 14, 1969 into a cloudy, rain-swept sky. Thirty-six seconds and again at 52 seconds after liftoff the Saturn V launch vehicle was struck by lightning and launch controllers lost telemetry contact momentarily. The booster's first stage continued firing, launching Apollo XII into an initial Earth-parking orbit of 115 by 117.9 miles. After one-and-a-half revolutions, during which the electrical circuits were checked out and no significant effects were noted, the S-IVB stage was re-ignited for a second burn of five minutes 45 seconds, placing Apollo XII into an initial free-return translunar trajectory. About 40 minutes later the CSM "Yankee Clipper" separated from the S-IVB-SLA, transposed, and docked with the LM "Intrepid." This was televised to Earth. The S-IVB stage was then jettisoned; however it failed to be inserted into the planned heliocentric orbit, due to the use of trajectory commands based on incorrect earlier data, and was placed instead into an elliptical Earth-orbit of 101,350 by 535,522 miles, with a period of 42 days. Conrad and Bean entered the LM to check for possible effects of lightning, found none, and re-entered the CSM for 10 hours of sleep. On November 15, the second telecast was made en route, showing the interior of the Yankee Clipper. Only one mid-course maneuver was needed; it

Apollo XII astronauts, left to right, Charles Conrad, Jr., Richard F. Gordon, Jr., and Alan L. Bean smile through the window of Mobile Quarantine Facility aboard the U.S.S. Hornet at the completion of their 10-day lunar mission.



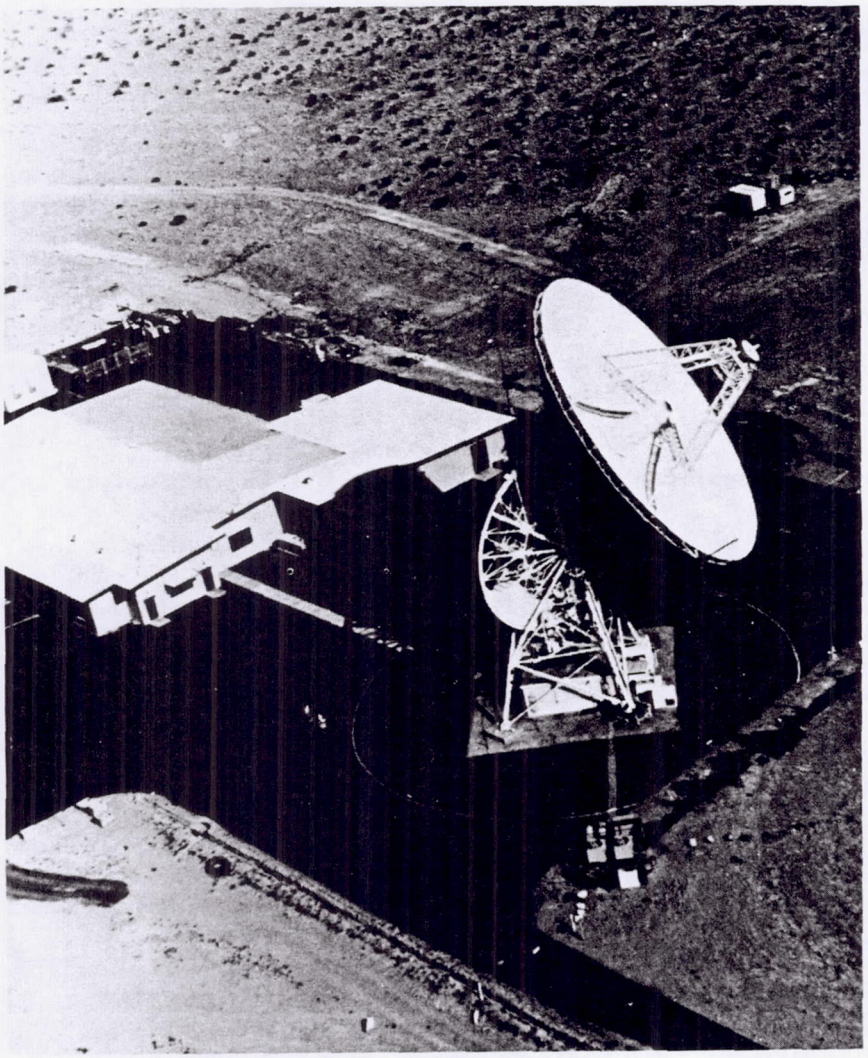
changed the Apollo XII's trajectory to prepare for later insertion into a non-free-return lunar orbit – the first "hybrid" trajectory in Apollo flights – and slowed the spacecraft so that it would arrive for a landing as planned with the most desirable solar illumination on the selected Site 7. Prior to lunar orbit insertion (LOI), a third telecast was made to Earth on November 17, showing the Earth, Moon, spacecraft interior, and intravehicular transfer of the crew. Later that day, when Apollo XII went behind the Moon, the first LOI burn began when the vehicle was about 97 miles up, and lasted for about six minutes, placing the spacecraft into an elliptical orbit of 69 by 195 miles. On November 18, two orbits later, and again on the lunar farside, a second LOI burn altered this to an orbit of 62 by 76 miles that was calculated to eventually circularize for the orbit of the soloing CSM, due to lunar-gravity potential, which would facilitate subsequent rendezvous and docking of the Intrepid with the Yankee Clipper in its Moon-parking orbit, after the scheduled lunar landing of the LM. The same day, Conrad and Bean entered the LM, and a telecast to Earth was made of the separation of the CSM and LM occurring 107 hours 54 minutes into the flight. On November 19, with the LM behind the Moon in the 14th orbit, and some 109 hours 23 minutes into the mission, the descent orbit insertion maneuver began, with the LMDE firing for 29 seconds, lowering the Intrepid's orbit to about 9 by 69 miles. After the LM came from behind the Moon and telemetry contact was re-established with Earth, a discrepancy was noted between orbit data readings from Intrepid and those displayed in Apollo Mission Control in Houston. The LM was initially believed to be in an incorrect descent orbit trajectory for landing in the desired region, due to normal mission anomalies. Using a newly developed "Lear" powered-flight data processor in Houston, the actual trajectory data as well as correction maneuvers information were fed by voice to the LM crew, enabling them to update the automatic down-range navigation computer program, shortening the range by 4190 feet and permitting the precision touchdown in the intended site. This update to a satisfactory trajectory occurred about two minutes after the LM began its powered descent, which had been initiated at about 110 hours 20 minutes into the mission, and which lasted a mere nominal 40 seconds longer than

the preflight plan had scheduled. With Conrad controlling the descent semi-manually for the last 500 feet, a precision landing was made at about 110 hours 32 minutes into the mission and closer to the target than expected: the Intrepid landed in the Ocean of Storms at 3°11′51″S. Lat. and 23°23′ 7.5″W. Long., about 120 feet northeast of Head Crater, and about 535 feet northwest from where Surveyor III stood in its crater. Apollo XII had touched down approximately 950 miles west of where Apollo XI had landed. Three hours after the landing and before the first EVA began, Gordon, orbiting 69 miles up in the Yankee Clipper, was able to sight both the Intrepid and Surveyor through the use of a 28-power sextant telescope. Conrad opened the Intrepid's hatch at 115 hours 10 minutes into the mission to begin the first lunar EVA for the Apollo XII crew. In their first lunar exploration, Conrad spent three hours 39 minutes outside Intrepid and Bean logged 2 hours 58 minutes on the lurain. During this EVA, Conrad collected lunar surface samples, and deployed both the erectable S-band communication antenna and the solar wind experiment. Bean was assigned to tripod-mount the TV camera; in the process of doing so it was inadvertently pointed into the sun and ceased to function. The ALSEP instrumentation and SNAP-27 RTG were deployed within an arc of 600 to 700 feet of the LM. The ALSEP functioned satisfactorily, except for two items in the package, and was expected to yield data for up to two years. Deployment of the ALSEP took about an hour to complete. Throughout this first EVA, Conrad and Bean also took various photographs of the experiment equipment, the spacecraft, the lurain, and of themselves. Before re-entering the Intrepid, Bean took a 16-inch-deep core sample of the lunar surface, and was followed back into the LM by Conrad. The first EVA ended at 119 hours five minutes into the mission, following which the crew ate, recharged their backpacks preparing for the second EVA the following day, and slept for about five hours. On November 20, an hour and a half earlier than planned, the crew began the second EVA when Conrad left the Intrepid some 131 hours 28 minutes into the mission. The second EVA included collection of 70 pounds of rock and dirt samples, the retrieval of between 10 and 15 pounds of randomly selected selenological samples, and further probing beneath the surface in two different areas to retrieve lunar material from depths up to 32 inches. The crew retrieved the TV camera and stored it in the LM for return to Earth. The most important part of this second EVA was a 5200-foot traverse of the lurain, ranging up to 1300 feet from the Intrepid. Walking northwest to the site of the ALSEP deployment, Conrad and Bean then turned south to perform a selenological rock survey. They skirted the rim of Head Crater, walked further south past Bench Crater, west around Sharp Crater, and back east past Bench Crater again, south of Halo Crater, and eventually turned northeast entering 650-foot-wide Surveyor Crater to retrieve parts of Surveyor III, which was perched some 150 feet from the edge at the southern quadrant. During the exploration, the astronauts discussed their findings by voice communication with geologists in Houston, who provided advice as to choice of samples to be retrieved. Surveyor was extensively photographed, before parts were retrieved. The 17-pound TV camera was severed from its mount, so that extensive study could be made on Earth of gears, motors, optics, metals, and lubricants to determine the effects of long exposure to the elements in the lunar environment. Similarly, the Surveyor's motorized scoop and pieces of TV cable, aluminum tubing, and glass were gathered.

Particular interest was attached to the cabling since a known quantity of biological organisms had been trapped within it, and scientists wished to learn if any had survived. Conrad and Bean then walked north, up a slope of about 14° into Block Crater located on the rim of Surveyor Crater, and turned west back to Intrepid, gathering further surface samples as they went, returning to the ship at 134 hours 49 minutes into the mission. Bean re-entered the LM at about 135 hours 10 minutes, and Conrad followed at 135 hours 22 minutes. The second Apollo XII EVA had consumed 3 hours 48 minutes. The crew removed their pressurized suits and jettisoned them on the Moon, and had a meal. Approximately six hours later on the same day, after a total of 31.6 hours on the Moon, the LM ascent stage was fired for about seven minutes and the Intrepid entered an initial orbit of 10 by 54 miles for rendezvous and docking with the Yankee Clipper three and a half hours later. The rendezvous and docking maneuvers were televised to Earth by Gordon in the Yankee Clipper. Following transfer to the CSM of Conrad and Bean and the materials retrieved from the Moon, the ascent stage was jettisoned and de-orbited by firing the ascent stage engine to impact on the Moon to provide predictable impact data for the ALSEP seismometer. Although planned to impact about six miles from the ALSEP, it landed about 40 miles away. The combined length and severity of the seismic disturbance set up by the impact, estimated to equal that of one ton of TNT, lasted, to the surprise of seismologists, with strong signals for more than a half hour, finally ceasing about an hour later. The effect was being studied, as was the data being received from the other experiments left on the Moon. A heavy schedule of photography of future landing sites on the lunar surface was conducted from the CSM, preceded by a change of plane maneuver 3.8° to the north, on the 39th lunar revolution of the CSM. The maneuver was performed by a 19-second burn of the SPS. Earlier, while the Yankee Clipper was in its 27th and 28th revolutions, CSM pilot Gordon had conducted the multi-spectral photographic survey of the lunar surface. During the 45th revolution, after 89 hours of lunar orbit by the CSM, and while on the far side, the SPS was ignited for inserting Apollo XII into a trans-Earth trajectory, which occurred 172 hours 27 minutes into the mission, on November 21. The return flight was uneventful. A mid-course correction maneuver was made on November 22, when Apollo XII was about 208,000 miles from Earth. On November 23, when the spacecraft was 108,000 miles from Earth, the crew held a televised news conference, following which the crew slept. A second scheduled mid-course correction maneuver was not needed. On November 24, following the same nominal re-entry procedure scheduled for Apollo XI, Apollo XII ended the 10-day flight by splashing down in the Pacific, at 15°46.6′S. Lat., 165°9′W. Long., about three miles from the target area, and three miles south of and within sight of the recovery ship USS Hornet. The splashdown occurred about 400 miles southeast of American Samoa, after a flight of 244 hours 36 minutes 25 seconds, just sixty-two seconds longer than planned.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell (NR), CM and SM spacecraft prime contractor; SPS, Aerojet-General, principal and subcontractors; AVCO, ablative heat shield;

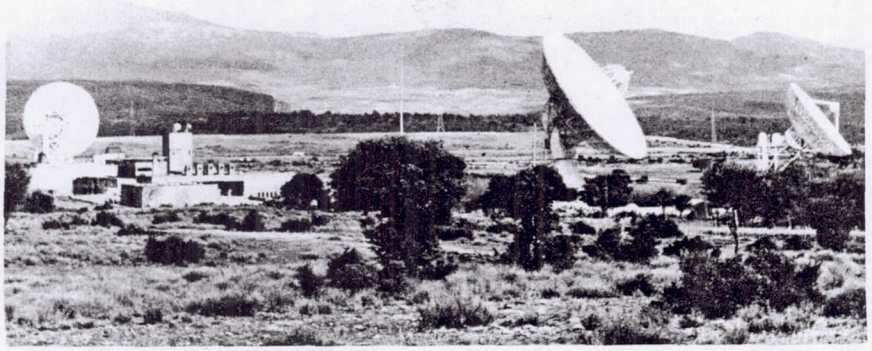
Collins, communication and data subsystems; Garrett, environmental control system; Grumman, LM spacecraft prime contractor; PGNS, General Motors (manufacturing), MIT (technical management), principal and subcontractors; NR, ascent engine; RCA, communication subsystem and radar and control electronics, TRW, descent engine and abort guidance system; Bendix, Apollo Lunar Surface Experiments Package prime contractor; Hamilton-Standard, astronauts' portable life support systems; ILC Industries, space suits; Bendix, Early Apollo Scientific Experiments Package; IBM, IU prime contractor; Boeing, Apollo-Saturn V technical integration and evaluation; GE, Apollo checkout equipment, related engineering design, quality management, and engineering support; TRW, mission trajectory control and spacecraft system analysis; NASA Marshall Space Flight Center, launch vehicle management; Boeing, first stage prime contractor; NR, second stage; McDonnell Douglas, third stage; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, Manned Space Flight Network management.

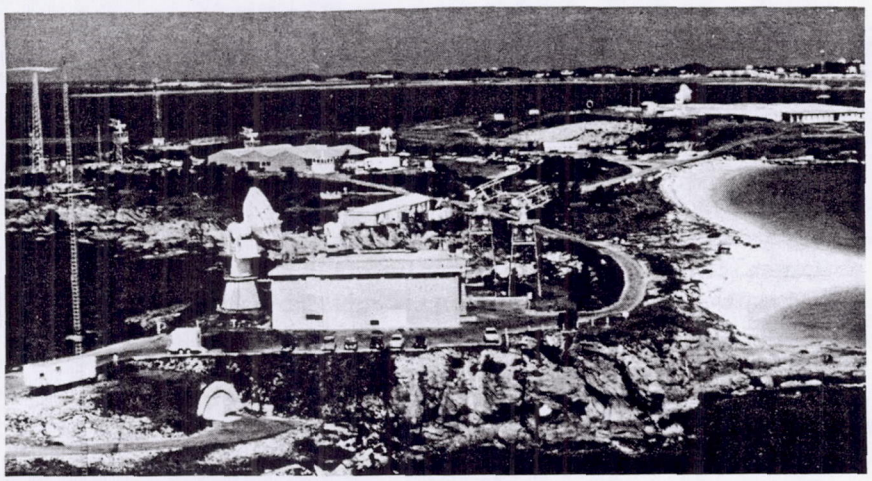


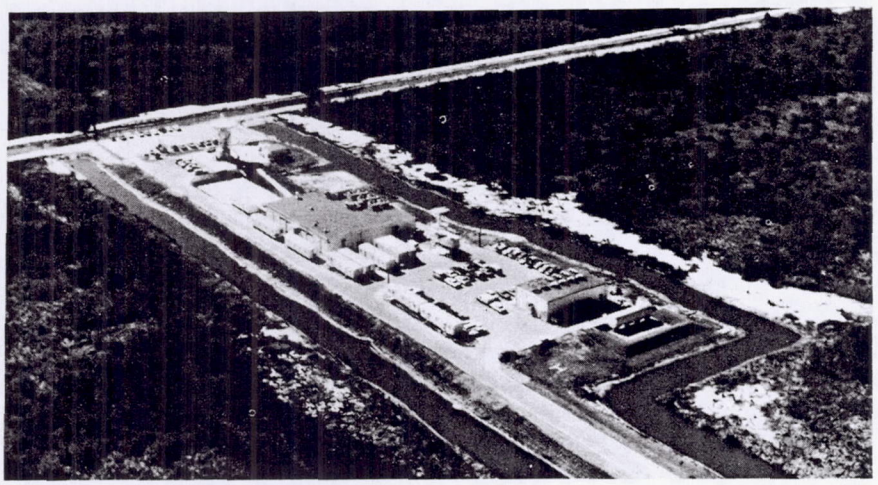
The large antenna dishes were the electronic "ears" for ground-based mission controllers. These complex facilities were built at strategic locations around the world and tied together by an intricate network of cables, relay stations, and communications satellites. Pictured at left is the Goldstone facility in the Mojave Desert, California.

Key Spacecraft Personnel		Affiliation
Apollo XII		
PM	R. Petrone	NASA Headquarters
PS	M.W. Molloy	NASA Headquarters
Apollo Lunar Excursion Module		
MG	F.I. Roberson	NASA Headquarters
SC	J.B. Hanley	NASA Headquarters
PM	W.F. Eichelman	NASA-JSC

Experiment	Experiment Personnel		Affiliation
Photos 70, 16 + 35MM	PI	Mapping Sciences Lab.	NASA-JSC
Photos Multispectral 5158	PI	A.F.H. Goetz	NASA-JPL
Window Meteoroid	PI	B.G. Cour-Palais	NASA-JSC
	OI	M.L. Brown	Lockheed Electronics
	OI	D.S. McKay	NASA-JSC
S-Band Transponder (S-164)	PI	W.L. Sjogren	NASA-JPL
Geologic Samples	PI	E.M. Shoemaker	California Institute of Technology
Solar Wind Spectrometer	PI	C.W. Snyder	NASA-JPL
	OI	D.R. Clay	NASA-JPL
	OI	M.M. Neugebauer	NASA-JPL
Passive Seismic Experiment	PI	G.V. Latham	University of Texas, Galveston
	OI	F. Press	Mass Institute of Technology
	OI	G.H. Sutton	University of Hawaii
Lunar Surface Magnetometer	PI	C.P. Sonett	University of Arizona
	OI	P. Dyal	NASA-ARC
Suprathermal Ion	PI	J.W. Freeman	Rice University
	OI	F.C. Michel	Rice University
	OI	H.K. Hills	
Cold Cathode Ion	PI	F.S. Johnson	University of Texas, Dallas
Dust Detector, Lunar	PI	B.J. O'Brien	Department of Environmental Protection
	OI	J.R. Bates	NASA-JSC
Solar Wind Composition	PI	J. Geiss	University of Berne
S-Band Transponders (S-164)	PI	W.L Sjogren	NASA-JPL
	CO	W.L. Sjogren	NASA-JPL







The Goddard-managed Manned Space Flight Tracking and Data Acquisition Network provided the links between the Apollo astronauts and Earth-bound mission controllers. Pictured here are tracking stations near Madrid, Spain (top), Bermuda (center) and Merritt Island, Florida (bottom). The latter two provided vital data during the initial phases of the mission.

Experiment	Experiment Personnel		Affiliation
Soil Mechanics	PI	J.K. Mitchell	University of California, Berkeley
	OI	D. Carrier	NASA-JSC
	OI	N. Costes	NASA-JSC
	OI	L.G. Bromwell	Massachusetts Institute of Technology

SKYNET A

Launch Vehicle – Long Tank Thrust-Augmented (LTTA) Delta: same as for Intelsat III F-5.

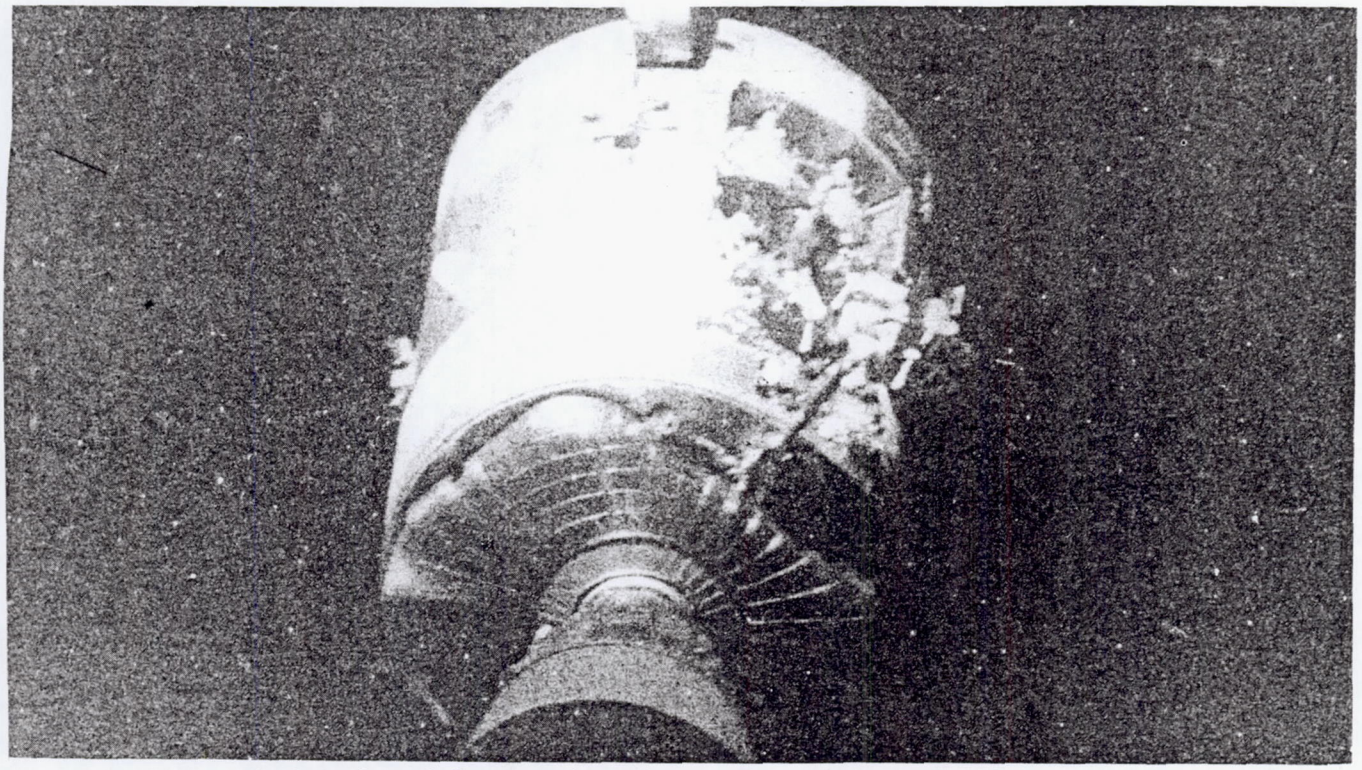
Spacecraft Description – Skynet A was a drum-shaped cylindrical main body, 54 inches in diameter, 32 inches high. A mechanically despun directionalized antenna projected from the top and an exhaust nozzle for a solid-propellant apogee motor used for insertion into synchronous orbit protrudes from the bottom, giving a total height of 62 inches. The body was covered by 7236 n-on-p solar cells, and is spin stabilized at 90 rpm. Weight (in geostationary orbit) 285 pounds.

Project Objectives – Initiation of satellite portion of the United Kingdom's defense communication network. After extensive integrated system checks of satellite and ground stations, Skynet A was to become operational by mid-1970.

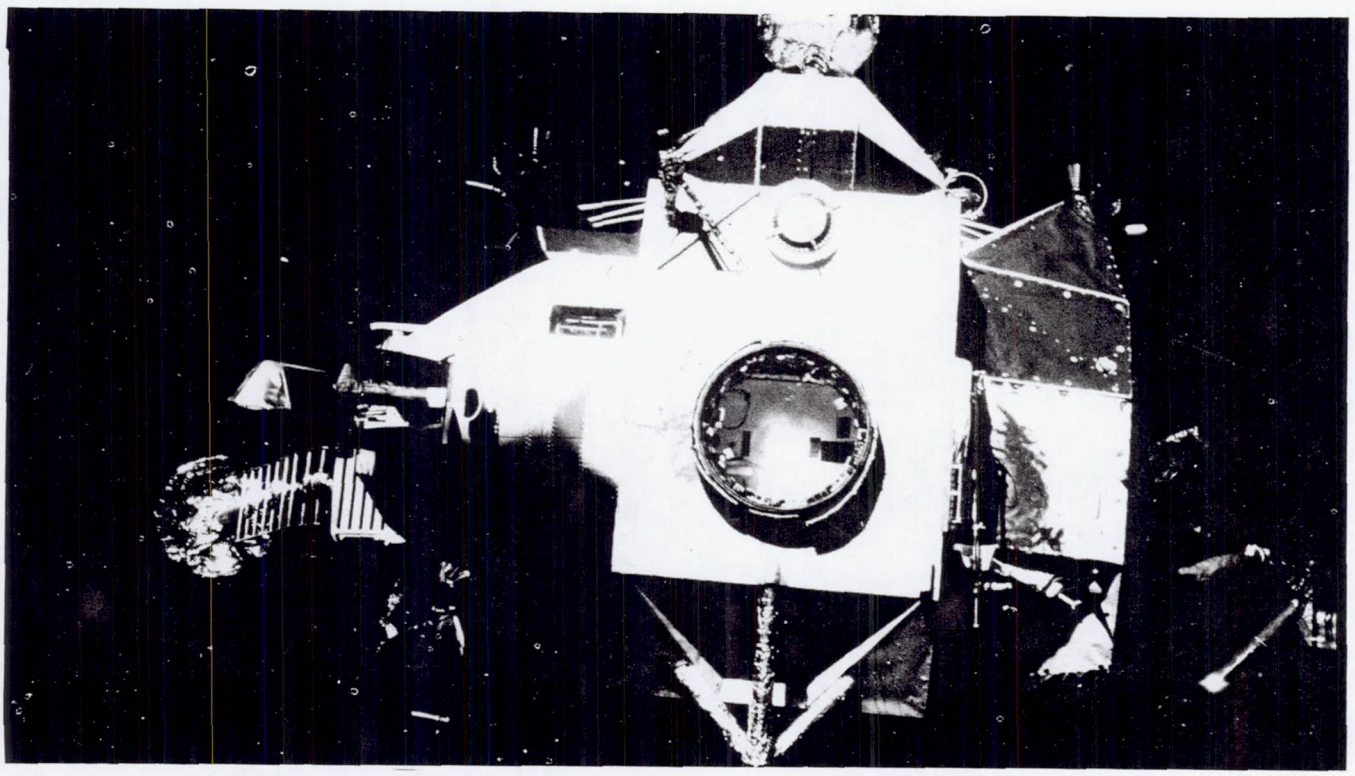
Spacecraft Payload – The augmented design of the spacecraft made use of essential redundancy to increase reliability and operational lifetime. Communication and telemetry was transmitted in the 375-400 mHz band. An X-band repeater operated between seven and eight gHz had two channels capable of receiving, frequency translating, amplifying, and 3.5-watt TWT final amplifiers coupled with the despun antenna yielded an ERP of 44.4 dbm. The despun antenna provided a gain of 18 db in the center of the beam, and 15 db within 9.5 degrees on either side, which was an order of magnitude greater than the signal from the earlier IDCSP design. The communication system featured dual IF amplifiers of 2 and 20 mHz bandwidth, with two channels in order to handle simultaneous traffic, separately and on a non-interference basis, both from high-powered fixed ground stations and low-powered mobile terminals. Command and telemetry were both coherent and noncoherent, and the command system accepted both discrete and proportional commands. Electrical power to back up the solar cells was supplied by two 16-cell nickel-cadmium batteries. A hydrazine reaction control system provided stationkeeping; torques were supplied by an orientation control system including sun and Earth sensors, that provided attitude and spin rate information and reference pulses for antenna pointing.

Project Results – Skynet A was launched on November 22, 1969 from Cape Kennedy into an initial elliptical orbit of 171.5 by 22,815.3 miles. After two days, the apogee motor was fired and the satellite was repositioned into an orbit of 21,559.5 by 22,791.7 miles, being moved to its permanent station over the Indian Ocean by the reaction control system. An extensive program of operational and qualification trials was begun, to determine satellite performance, assess expected lifetime, and detect any system faults that could be used to make design changes, if necessary, to later satellites.

Major Participants – United Kingdom's Ministry of Defense and Ministry of Technology, program management; USAF Space and Missile Systems Organization, spacecraft management; Aerospace Corporation, systems engineering and technical direction contractor; Philco-Ford, spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.



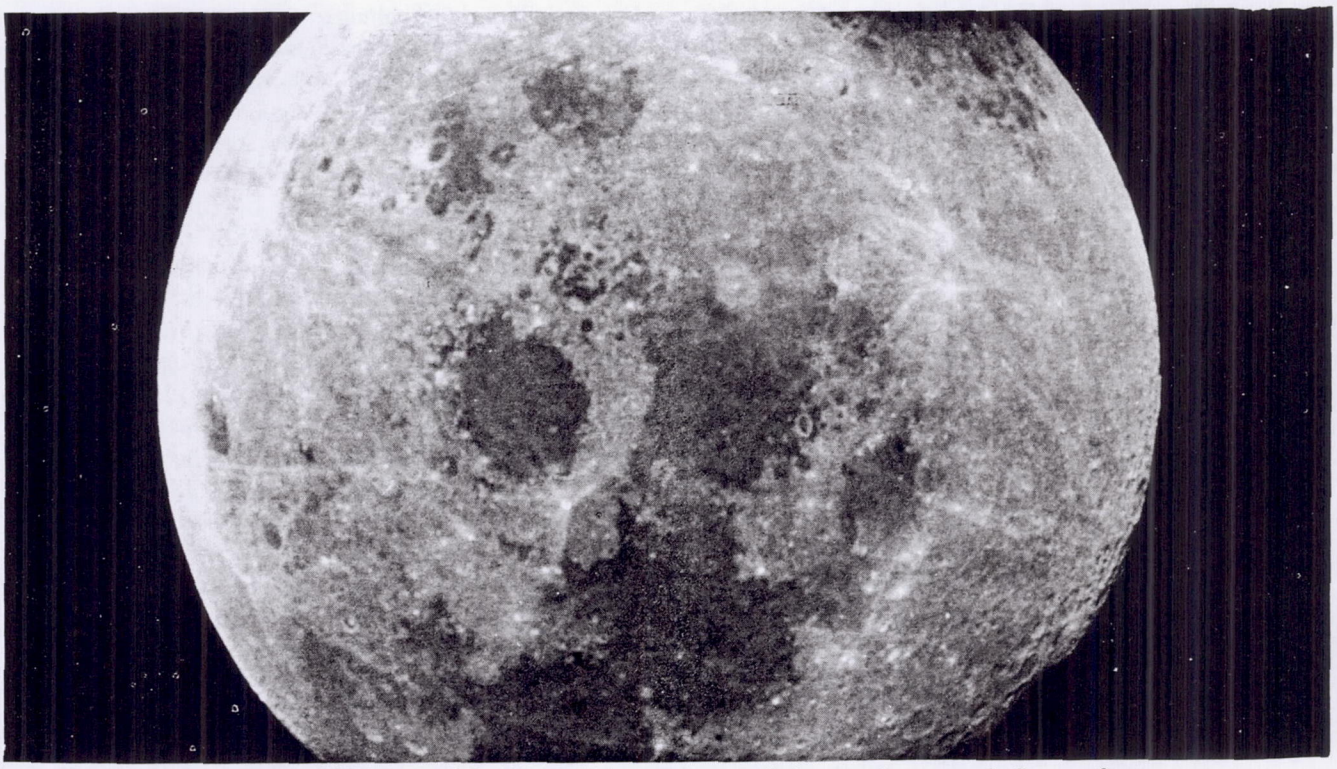
A mission in peril. Oxygen tank number two after explosion in the service module of Apollo XIII.



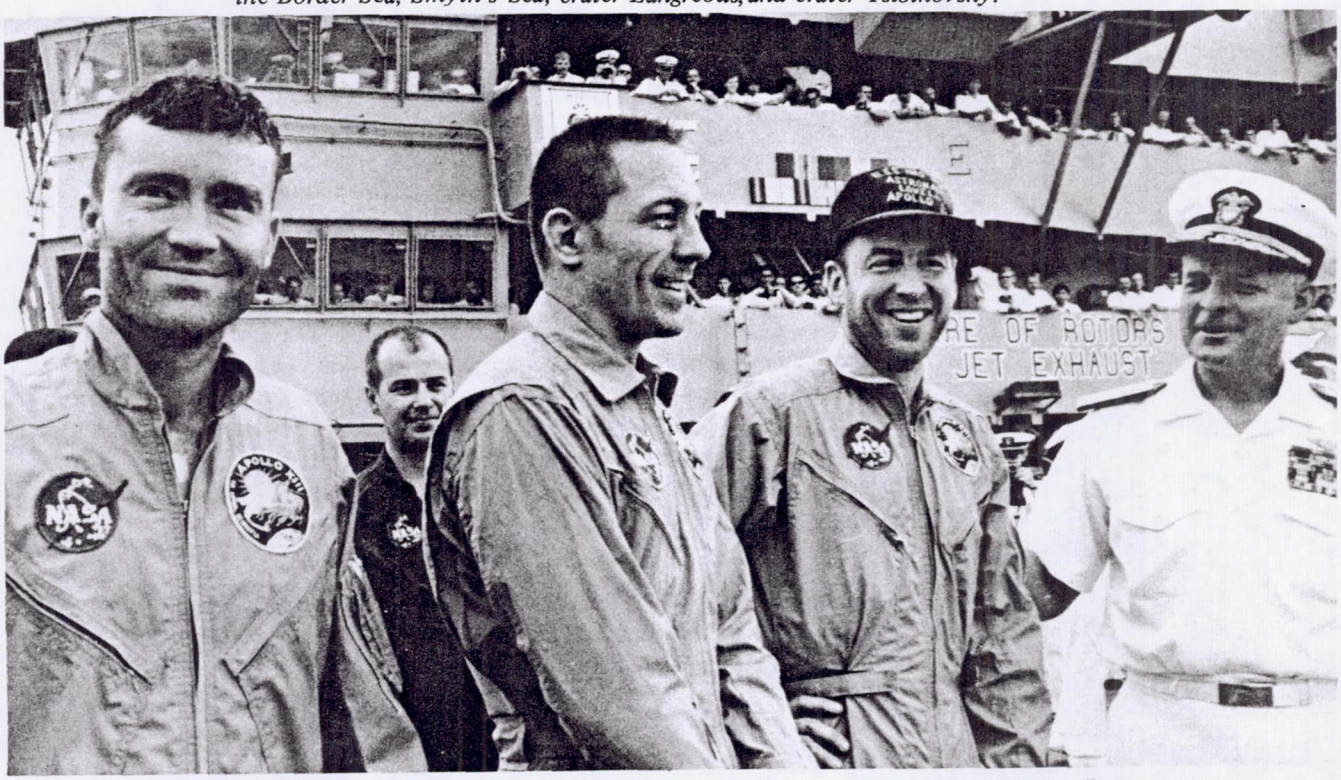
The lunar module was jettisoned after the explosion. Apollo XIII astronauts depended on the lunar module for life support.

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1970



Apollo XIII view of the Moon during a transearth journey homeward. Some of the lunar features shown include the Sea of Crisis, the Sea of Nectar, the Sea of Vapors, the Border Sea, Smyth's Sea, crater Langreous, and crater Tsiolkovsky.



A safe return after perilous space flight. Apollo XIII crew, from left, Fred W. Haise, Jr., lunar module pilot; John L. Swigert, Jr., command pilot; and James A. Lovell, Jr., commander are being greeted aboard the USS Iwo Jima by Rear Admiral Donald C. Davis, commanding officer of Task Force 130, Pacific Recovery Forces.

INTELSAT III FLIGHT 6, FLIGHT 7, FLIGHT 8

Background – Intelsat satellites were projects of the International Telecommunications Satellite (Intelsat) Consortium, comprising of a partnership of some 82 nations formed to establish a global commercial satellite system. The U.S. participant in Intelsat was the Communications Satellite (Comsat) Corporation, which acted as manager on behalf of the consortium. The space segment of the system was owned by Intelsat, and the ground stations were owned by public or private organizations in the countries where located. NASA launched the satellites and was reimbursed for launch service costs. Intelsat I (Early Bird) was launched in April 1965; Intelsat IIA (Lani Bird), October 1966; Intelsat IIB (Pacific 1), January 1967; Intelsat IIC (Atlantic 2), March 1967; and Intelsat IID (Pacific 2), September 1967. In September 1968, Intelsat III F-1, the first launch attempt in the Intelsat III series, failed when a launch vehicle malfunction forced the range safety officer to destroy the vehicle in flight. Intelsat III F-2 was launched in December 1968 and positioned over the Atlantic. Intelsat III F-3, launched February 1969, was initially placed over the Pacific Ocean; but due to a malfunction causing a decrease in capacity, it was repositioned over the Indian Ocean where it was providing sufficient service for traffic in that region. Intelsat III F-4, launched in May 1969, was positioned over the Pacific. Intelsat III F-5, launched in July 1969, entered an improper elliptical orbit due to third stage malfunction, making geostationary positioning impossible. Intelsat III F-6, launched in January 1970, and F-7, launched April 1970, both were positioned over the Atlantic. The last of the Intelsat III series, F-8, was launched in July 1970, but failed to achieve synchronous orbit due to a malfunction of the apogee motor firing. The next phase: Intelsat IV was to include five operating satellites over the Atlantic, Pacific and Indian Oceans (supplemented by two in-orbit spares). Intelsat IV F-2 was launched in January 1971 and Intelsat IV F-3 was launched in December 1971. Both were in commercial service over the Atlantic. A third of the operating satellites was expected to complete the global Intelsat IV system.

Launch Vehicle – Long Tank Thrust-Augmented Delta: modified Thor first stage with 172,000 pounds thrust augmented by three strap-on solid propellant rockets for a combined thrust of 333,500 pounds; second stage, 7,800 pounds thrust; solid propellant third stage, 5,700 pounds thrust.

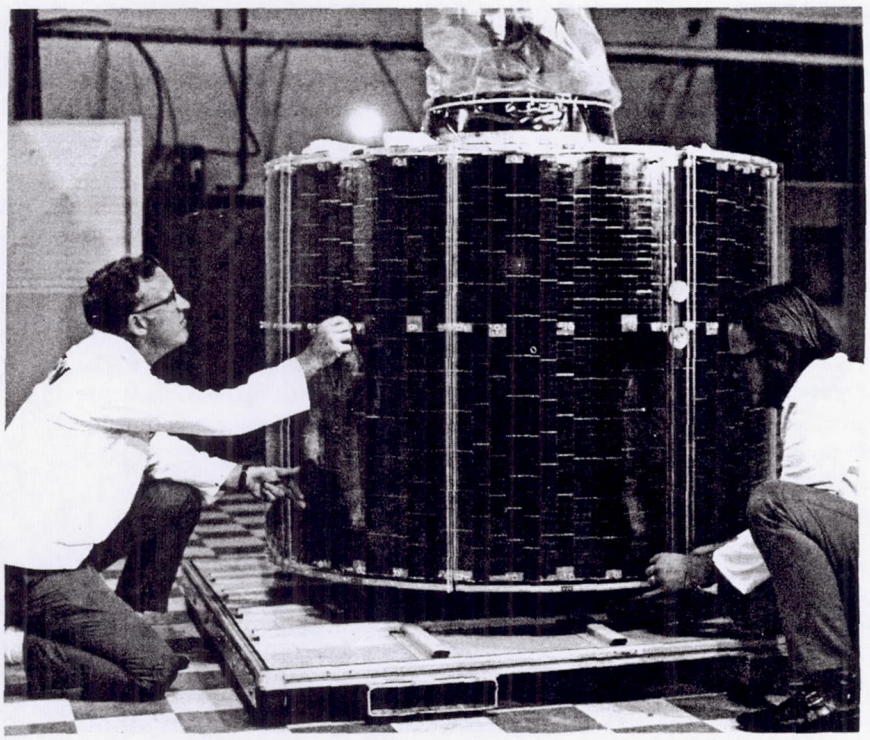
Spacecraft Description – Satellites in this series were identical: each had a central magnesium cylinder in which apogee motor and communications antenna were positioned, circular equipment platform surrounding cylinder, and solar cell panels attached to equipment platform. Diameter was 56 inches and height, 41 inches. On top of central cylinder was doughnut-shaped toroidal beam antenna. Protruding from center was flat plate mechanically despun communications antenna. Satellite was spin stabilized at nominal 90 rpm. Overall height: 78 inches. Average weight at orbital insertion: 342 pounds.

Project Objectives – Intelsat III F-6, F-7, and F-8 were launched to augment global communications satellite network, and to replace earlier satellites which were being removed from service.

Spacecraft Payload – The communications subsystem utilized a mechanically despun directional antenna and dual transponders to receive at 5930 to 6420 MHz and transmit at 3695 to 4195 MHz. It had a design capacity of 1,200 circuits, four television channels or any combination of these. The solar cells generated 130 watts for spacecraft power and for recharging a 2-cell nickel-cadmium battery which provided power during eclipse. Attitude and station keeping were provided by two nitrogen pressurized monopropellant hydrazine propulsion systems, each employing a pair of tanks to supply one radial and one axial thruster.

Project Results – Intelsat III F-6 was launched from Cape Kennedy, Fla., on January 14, 1970, and became operational over the Atlantic at 336°E. Long. on February 1, 1970. It has since been moved to 319°E. Long. Intelsat III F-7 was launched on April 22, 1970, and became operational over the Atlantic at 341°E. Long. on May 1, 1970. Intelsat III F-8 was launched on July 23, 1970, but failed to achieve synchronous orbit due to a malfunction during apogee motor firing.

Major Participants – International Telecommunications Satellite Consortium, spacecraft ownership; Communications Satellite Corp., spacecraft management; TRW, spacecraft prime contractor; NASA Goddard Space Flight Center, launch vehicle management; McDonnell Douglas, launch vehicle prime contractor.



Pre-launch checkout of Intelsat III, a synchronous orbiting satellite serving global commercial communications.

ITOS – 1, OSCAR 5

Launch Vehicle – Two stage Delta-N which, for the first time, used six strap-on solid-fuel rockets. First stage (modified Air Force Thor) produced 325,000 pounds of thrust, including three Castor I solid rockets ignited at launch. Second stage produced 7,800 pounds thrust. The three Castor II solid rockets were ignited at about 46,000 feet altitude. The extra solid-strap-ons were required to place the heavier ITOS spacecraft into a 900-mile orbit.

Spacecraft Description – ITOS 1: Also designated TIROS-M, this second generation spacecraft was box-shaped (40 by 40 by 48 inches), 14 feet wide with solar panels deployed. It was Earth oriented and three-axis stabilized to within one degree and powered by 10,000 negative-on-positive solar cells mounted on three identical panels 3 feet by 5 feet, producing 250 watts of average power. Total solar array area was 48 square feet. Spacecraft carried four antennas: command and beacon, two real-time antennas, and a play-back (S-band) antenna. Thermal control subsystem was composed of a geometrically variable absorption surface on upper face of the spacecraft, variable emittance surfaces on two equipment panels, a fixed radiator on the baseplate, and remaining surfaces covered with multifoil-layer insulation blankets. Spacecraft weight: 682 pounds.

OSCAR 5: Orbiting Satellite Carrying Amateur Radio. Box-shaped, 12 by 17 by 6 inches, weighing 39 pounds, passively stabilized by eddy current loops and bar magnet; four steel tape antennas, and powered by 28 Size G alkaline manganese cells weighing 20 pounds.

Project Objectives – ITOS-1: Double the daily weather coverage from the series of Environmental Survey Satellites; take infrared pictures of the Earth's cloud cover at night and transmit cloud top and surface temperatures to Automatic Picture Transmission system ground receiving units every 12 hours. The ITOS system was a joint effort of NASA and the Department of Commerce's Environmental Science Services Administration. All ITOS spacecraft were launched and checked out in orbit by NASA before they were turned over to the user agency.

OSCAR 5: This fifth in a series of amateur-built and operated radio satellites was designed to transmit low-power signals to be used by radio amateurs throughout the world for training in satellite tracking and for experiments in radio propagation. Satellite lifetime was approximately two months, based on continuous operation of the two meter transmitter and weekend operation of the higher power 10-meter transmitter.

Spacecraft Payload – ITOS-1: Primary meteorological sensors included two Advanced Vidicon Camera System (AVCS) cameras for storing pictures of the world's weather; two Automatic Picture Transmission (APT) cameras for direct readout at small ground stations; and two scanning radiometers (infrared) for sending direct APT pictures as well as recording the entire Earth's weather at nighttime for playback. Secondary meteorological sensors are a Flat Plate Radiometer (FPR) and a Solar Proton Monitor (SPM). These sensors were designed to measure proton flux levels at the satellite altitude.

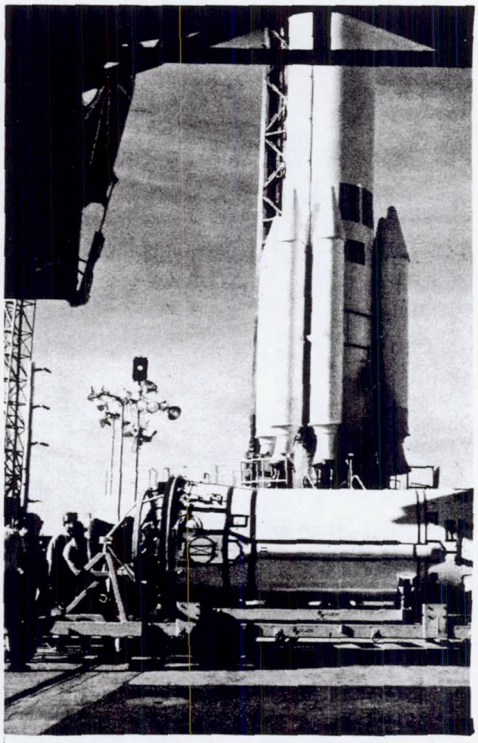
OSCAR 5: Spacecraft carried one 150 milliwatt transmitter operating at 29.45 MHz in the 10-meter band, one 50 milliwatt transmitter operating at 144.05 MHz in the two-meter band, a command receiver and decoder as part of a seven channel telemetry system, and three orthogonal optical horizon sensors.

Project Results – Successfully launched January 23, 1970, from the Western Test Range, Vandenberg AFB, Calif. ITOS-1 was placed in a 89.3 by 918.7 mile orbit, with an inclination of 101.99 degrees (posigrade) and a period of 115 minutes. After a five-month engineering checkout by NASA, the satellite was turned over to ESSA for operational duty on June 15, 1970. OSCAR 5 was placed into a 880 by 910 mile orbit, with an inclination of 101.56 degrees, and a period of 115 minutes. All systems operated successfully, with the two-meter beacon lasting until February 14, 1970 (23 days) and the ten-meter beacon lasting until March 9, 1970 (46 days), when the spacecraft reached end-of-life with depletion of its chemical batteries, as expected. The VHF beacon operated for 281 orbits; the HF for 562. Project was considered a major success based on the interest it generated within the amateur and short-wave listener community throughout the world. Tracking reports were received from several hundred stations in 27 countries by the University of Melbourne in Australia.

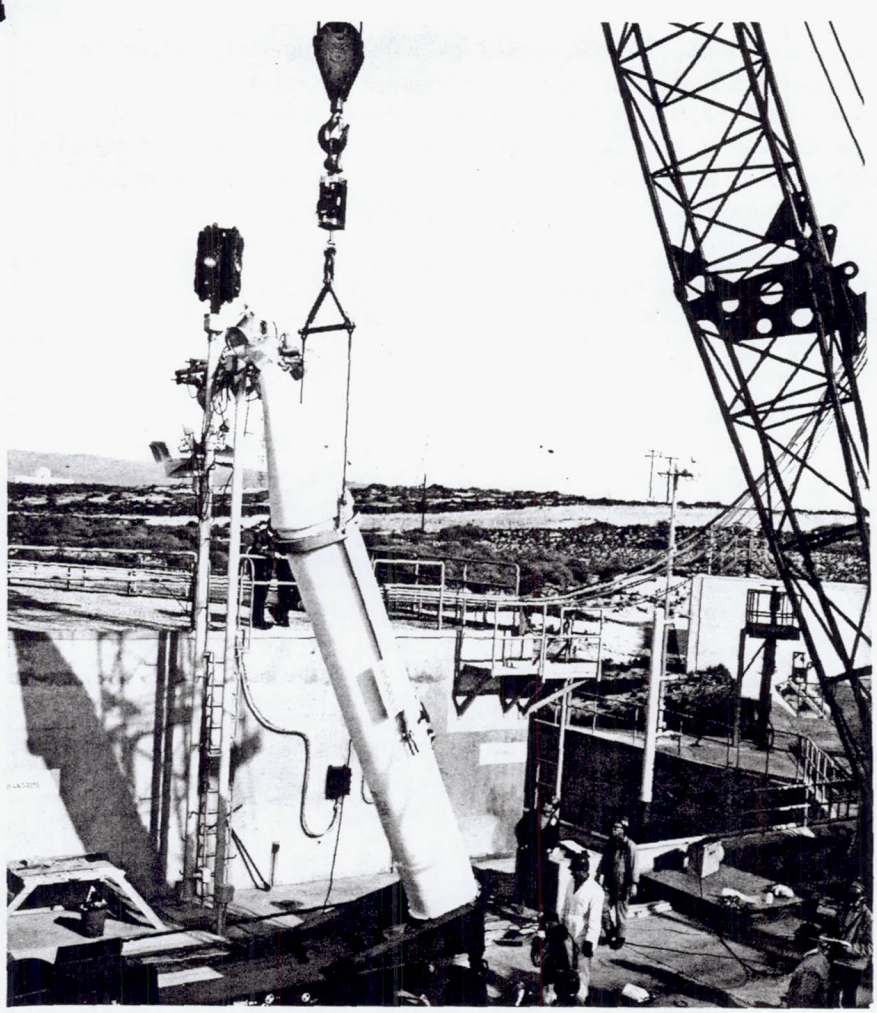
Major Participants – NASA Goddard Space Flight Center, ITOS1 spacecraft management; RCA, spacecraft prime contractor; Project Australis, University of Melbourne, OSCAR 5 spacecraft management and construction; The Radio Amateur Satellite Corporation, spacecraft launch preparation; McDonnell Douglas, launch vehicle prime contractor; Kennedy Space Center and KSC Unmanned Launch Operations at WTR, launch operation.

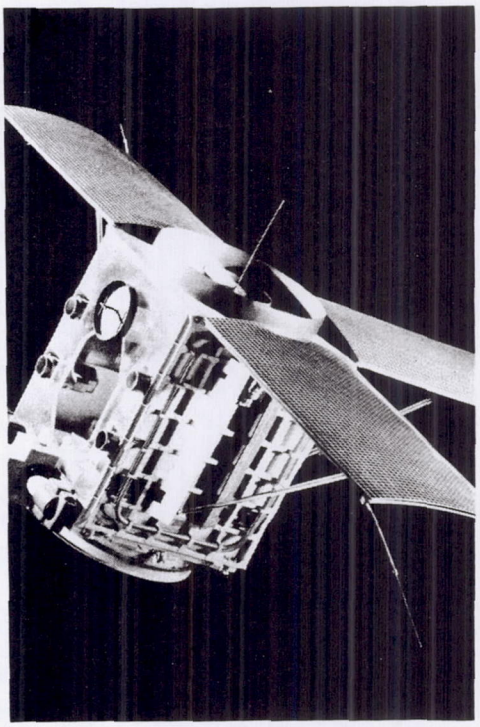
Key Spacecraft Personnel		Affiliation
OSCAR 5		
PM	Unknown	Unknown
PS	Wia	University of Melbourne
CO	P. I. Klein	Amsat Corporation

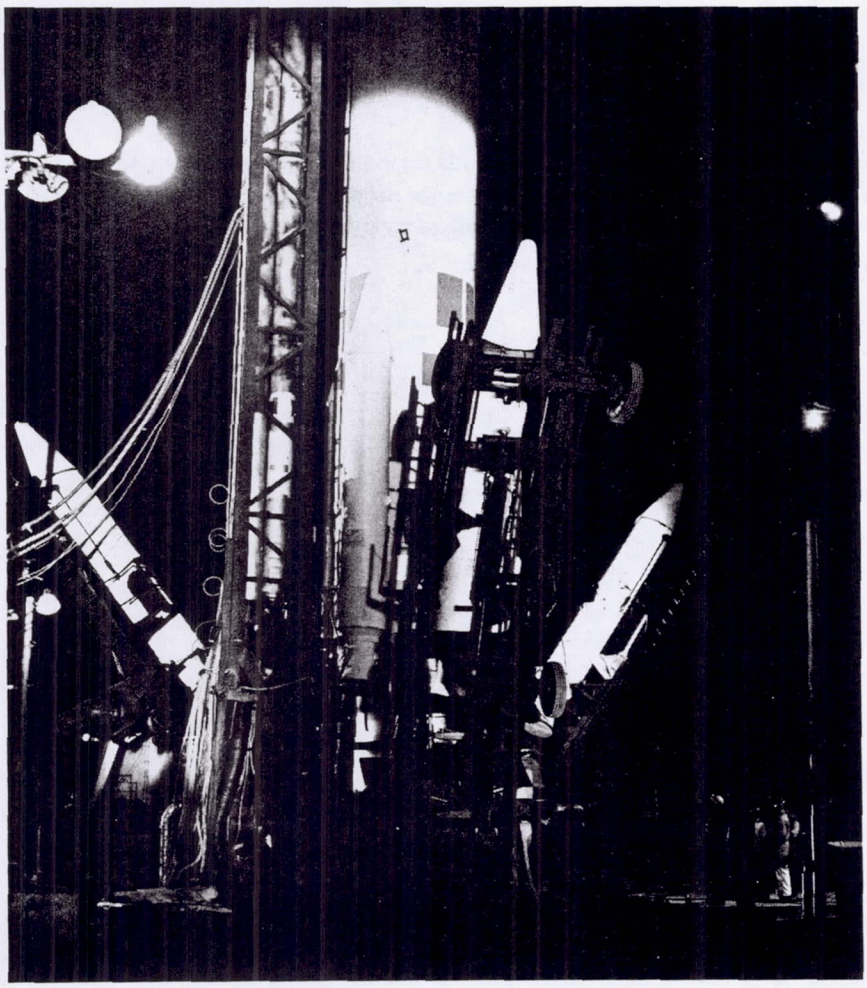
Experiment	Experiment Personnel		Affiliation
OSCAR 5			
Telemetry + Tracking Beacon	PI	Wia	University of Melbourne
	CO	P. I. Klein	Amsat Corporation



Above and right, assembling Delta launch vehicle, with strap-on boosters to launch ITOS-1/TIROS-M.







Above, ITOS-1/TIROS-M spacecraft made daytime and night time cloud cover observations obtained in both direct and stored modes of operation.

SPACE ELECTRIC ROCKET TEST (SERT II)

Launch Vehicle – Thorad Agena D.

Spacecraft Description – Included Agena vehicle stage 60 inches in diameter by 248 inches long, two solar arrays (5 by 19 feet) containing 33,300 solar cells generating 1,471 watts of power, a spacecraft support unit, spacecraft ring (59 inches by 40 inches) and two electron-bombardment ion engines each generating 0.006 pound thrust by ionizing a vaporized propellant (mercury) electrically, accelerating the ions, neutralizing these ions and expelling them at speeds of 50,000 miles per hour. Total spacecraft weight: 3,100 pounds.

Project Objectives – To provide the first orbital test of electron-bombardment ion engines, with one engine scheduled to operate continuously for at least six months; following a one to three-month period of darkness, the second ion engine was to be operated continuously for eight months. In addition to determining operating characteristics of the engines, the mission also sought to determine whether long-duration operation of the ion engines presented any problems in radio communications between the spacecraft and Earth, the electrical compatibility of the thruster system and the rest of the spacecraft, and whether exhaust products would cause degradation of solar cells or the thermal control and optical properties of various surfaces. Measurement on thruster efficiency variations included: interactions, or coupling, if any, between the ion beam and the surrounding plasma of space; thrust magnitudes, and temperature fluctuations of an optically reflective coating.

Spacecraft Payload – Two hollow cathode ion bombardment engines, 58 pounds of mercury propellant (29 pounds for each engine), various power conditioning and switching units, and telemetry system.

Project Results – SERT II was launched February 4, 1970, from the Western Test Range, Vandenberg AFB, Calif.; and placed in near circular polar orbit of 618 by 625 miles. Inclination to the equator was 99.13 degrees and the period was 105.2 minutes. The first engine was turned on February 14, initially at 30 percent thrust, then increased to 80 percent, and finally to full rated thrust. It was then shut down and the second engine turned on, brought up to thrust and left on. On May 24, 1970, the radio interference experiment ceased operation after supplying more than three months of useful data. After more than five months of operation (3,785 hours), an electrical short in the operating engine caused an early shutdown. Seven unsuccessful attempts to restart the thruster led to a decision to start the other ion engine on July 24. On October 17, that engine failed after operating 2,011 hours, or nearly three months. Analysis later indicated failure of each thruster was caused by an electrical short in its high voltage power supply system. On January 15, 1971, NASA officially designated the mission as unsuccessful. Although falling short of its mission duration objective by less than one month, most of its secondary experiment objectives were met. The agency considered the mission a significant advancement in electric ion propulsion.

Major Participants – NASA Office of Advanced Research and Technology, program management; NASA Lewis Research Center, spacecraft and launch vehicle project management; Kennedy Space Center, Western Test Range, launch operations; NASA Goddard Space Flight Center, tracking and data acquisition; McDonnell-Douglas, launch vehicle prime contractor; Lockheed Missiles and Space Company, Agena prime contractor.

NATOSAT – I AND NATO – B

Launch Vehicle – Thrust Augmented Thor-Delta. Same as OSO VII.

Spacecraft Description – Satellites were identical. Structure was a cylinder 54 inches in diameter and 63 inches high, with a mechanically despun antenna projecting from the top. The solar power array contained eight vertical panels with more than 7,000 solar cells, supplemented by two 16-cell nickel cadmium batteries. Launch weight: 535 pounds. In orbit weight: 285.

Project Objectives – Communication and satellites linked North Atlantic Treaty Organization headquarters in Brussels with the capitals of member nations and the NATO commands on land and sea.

Spacecraft Payload – Each spacecraft had two transponders, each with two channels to receive, frequency translate, amplify and re-transmit the traffic originated by the ground stations. Dual intermediate frequency modules provided channels for large fixed ground stations developing high power and separate channels for small terminal users such as ships and the mobile land units. Satellites had on-board rocket motors which ignite after five orbits to circularize the orbit. Expected mission lifetime was five years.

Project Results – NATOSAT-I was launched from Cape Kennedy on March 20, 1970, and maneuvered into a 22,000 mile orbit on March 22. NATO B, launched February 2, 1971, joined its sister spacecraft in synchronous orbit, also 22,000 miles above the equator. Both were functioning satisfactorily and were being used periodically – one for tests with new ground stations as they came on line and the other for regular communications between operational ground stations.

Major Participants – North Atlantic Treaty Organization SATCOM, program management; USAF Satellite Control Facility, command and control; Aerospace Corp., systems engineering and technical direction; Philco-Ford, spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.

NIMBUS IV, TOPO 1

Launch Vehicle – Thorad-Agena D. Uprated version of the Thrust-Augmented Thor with an Agena second stage. Thor first stage had 170,000-pound thrust augmented by three strap-on solid rocket motors providing total first stage thrust of 326,000 pounds. Agena D second stage had 16,000 pounds thrust. Vehicle height was 109 feet.

Spacecraft Description – Nimbus IV: Appearance similar to earlier spacecraft in the series. Butterfly-shaped with 5-foot diameter sensory ring lower section which housed experiments and supporting equipment. A hexagonal upper section contained the attitude control system. Two solar panels, 8 feet by 3 feet, provided more than 200 watts of power supplemented by two SNAP-19 generators. Overall height was 10 feet; width, was 11 feet. The spacecraft was three axis stabilized and Earth-looking. Orbital weight was 1,366 pounds.

TOPO 1: Piggyback tactical satellite survey system of the SECOR type. Rectangular package with one-foot long sides was covered with solar cells. Weight was 48 pounds.

Project Objectives – Nimbus IV: Continuation of spacecraft series to serve as testbed for research and development of new meteorological sensors, subsystems and system configurations. Some of the technology developed in the Nimbus program was transferred to TIROS operational weather satellites. Meteorological objectives were to study spatial and temporal distribution of the atmospheric structure, particularly temperature, ozone, and water vapor, and to determine temporal variation in the solar radiation in the near ultraviolet, particularly ultraviolet absorption by the atmosphere.

TOPO 1: Contributing mission to the Army's overall position determination program, and for triangulation exercises for ground tactical positioning.

Spacecraft Payload – Nimbus IV: Of the nine experiments, four were new and five were improved versions of experiments on earlier flights. New experiments included: backscatter ultraviolet spectrometer; filter wedge spectrometer; selective chopper radiometer; and temperature, humidity and infrared radiometer. Others were image dissector camera system; infrared interferometer spectrometer; interrogation, recording and location system; ultraviolet solar energy monitor; and satellite infrared spectrometer.

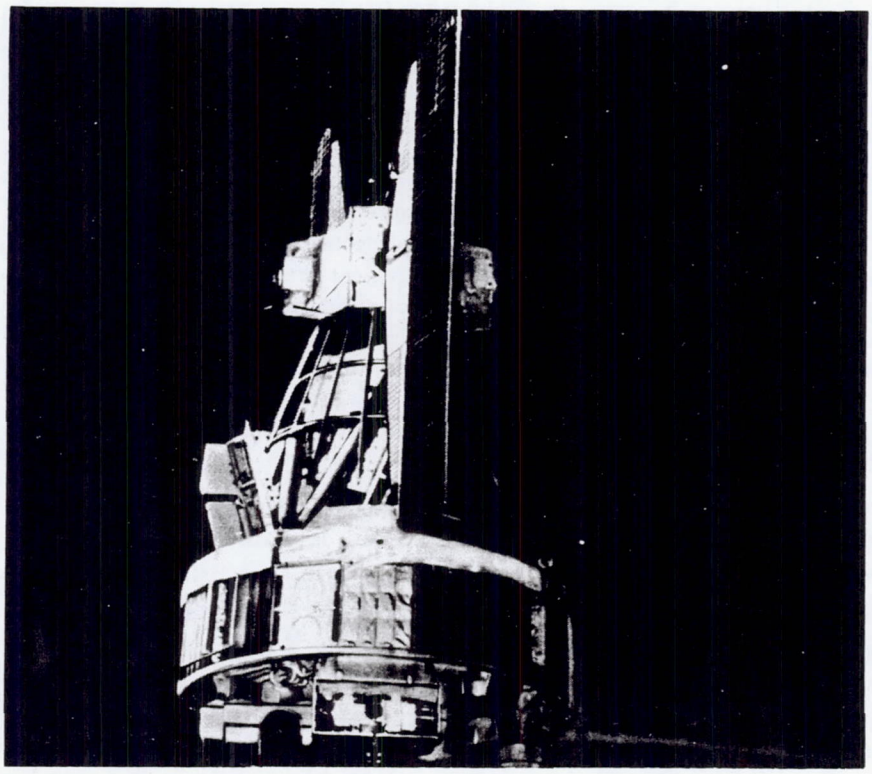
TOPO 1: Included a transponder and antenna system for space-ground triangulation exercises.

Project Results – Launched April 8, 1970, from Vandenberg AFB, Calif. Nimbus IV was positioned in the planned circular, near-polar orbit, making world-wide weather observations twice a day – once in daylight and once in darkness. TOPO 1 operated in an elliptical orbit up to 2,500 miles.

Major Participants – NASA-Goddard, Nimbus spacecraft management and overall system responsibility; General Electric, structure, supporting systems and spacecraft integration and test; NASA-Goddard, Oxford University, ESSA, University of Wisconsin, University of Maryland, experimenters;



Photograph of a storm straddling the British Isles was received by means of the Real Time Transmission System aboard Nimbus III. It was recorded on August 16, 1970 as the "worst weather thrashing in August for years."



Nimbus IV, NASA's advanced research and development weather satellite observing Earth's cloud cover and temperatures.

NASA-Lewis, launch vehicle management; McDonnell Douglas, first stage contractor; Lockheed, second stage contractor; U.S. Army Engineers Topographic Laboratory, TOPO management.

Key Spacecraft Personnel		Affiliation
Nimbus IV		
PM	C. M. Mackenzie	NASA-GSFC
PS	M. Tepper	NASA-GSFC
CO	G. J. Delio	NASA-GSFC
CO	P. J. Crossfield	NASA-GSFC
MG	R. J. Arnold	NASA Headquarters
Topo 1		
PM	F. Varnum	USA Topo Command

Experiment	Experiment Personnel		Affiliation
Nimbus IV			
Solar Ultraviolet Monitor	PI	D. F. Heath	NASA-GSFC
Temperature-Humidity Iridium Radiation	PI	A. W. McCulloch	NASA-GSFC
	OI	I. L. Goldberg	NASA-GSFC
Iridium Interplanetary Spectrometer	PI	R. A. Hanel	NASA-GSFC
Satellite Iridium Spectrometer	PI	D. Q. Wark	NOAA-NESS
	OI	D. T. Hilleary	NOAA-NESS
Backscatter Ultraviolet Spectrometer	PI	D. F. Heath	NASA-GSFC
	OI	J. V. Dave	IBM Corporation
	OI	A. J. Krueger	NASA-GSFC
	OI	C. L. Mateer	Environment Canada
Image Dissector Camera	PI	G. A. Branchflower	NASA-GSFC
	OI	E. J. Werner	NASA-GSFC
Interrogation Location System	PI	C. E. Cote	NASA-GSFC
	OI	F. Saiedy	University of Maryland
Filter Wedge Spectrometer (H20)	PI	W. A. Hovis	NOAA-NESS
Selective Chopper Radiometer	PI	J. A. Houghton	Oxford University
	OI	S. D. Smith	Reading University
Cloudcover Mapping	PI	L. L. Foshee	USA Electronics Command
	OI	R.E. Samuelson	NASA-GSFC

APOLLO XIII

Launch Vehicle – Saturn V (SA 508): almost identical to those for the Apollo VIII through XII missions. S-IC first stage, with five F-1 engines burning RP-1 (kerosene) fuel and liquid oxygen, produced approximately 7,584,593 pounds of thrust at liftoff, building to about 8,955,108 pounds at cutoff. S-II second stage (about 3,000 pounds lighter than on previous Saturn V vehicles due to use of closed-cell polyurethane spray-on foam insulation on the exterior of the stage) was powered by five J-2 engines, producing about 1.16 million pounds of thrust during flight and using liquid hydrogen and liquid oxygen as propellants. S-IVB third stage with its single gimbaled J-2 engine which could be shut off and restarted, developed a maximum thrust of 230,000 pounds. Total height of the Apollo XIII stack (launch vehicle and spacecraft sections), including spacecraft launch escape system, was 362.8 feet. Total weight at ignition: 6,395,647 pounds.

Spacecraft Description – Apollo XIII exceeded all previous spacecraft in launch weight, totalling 110,210 pounds. Command Module 109 weighed 12,572 pounds; LES, 9,021 pounds, SM 109, 51,099 pounds; Lunar Module 7, 33,483 pounds "wet;" and spacecraft-LM adapter (SLA), 4,044 pounds. Dry weight of Command Module "Odyssey" was 12,327 pounds, and LM "Aquarius" was 9,915 pounds.

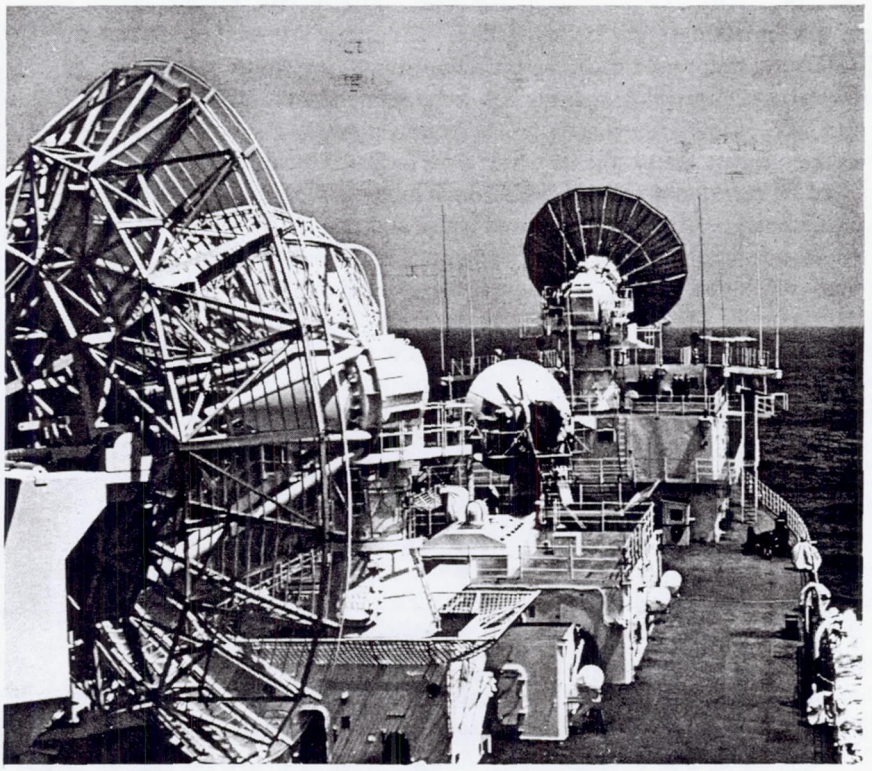
Project Objectives – Selenological inspection, survey and sampling of materials in a pre-selected region of the Fra Mauro formation; deployment and activation of an Apollo Lunar Surface Experiments Package (ALSEP); developement of man's capability to work in the lunar environment; and photography of candidate exploration sites. Other mission objectives included lunar surface close-up photography, a solar wind composition experiment, television coverage of lunar surface activities, evaluation of landing accuracy techniques, evaluation of extra-vehicular activity (EVA) communications systems performance, collection of data on lunar soil mechanics, dim-light photography, selenodetic reference point update, orbital science photography, and transearth lunar photography. The empty S-IVB third stage of the launch vehicle was targeted to impact on the moon prior to lunar landing and its impact to be recorded by the seismometer left by the Apollo XII crew.

Spacecraft Payload – Apollo XIII carried two color and one backup black & white television cameras. Color cameras were essentially identical except for additional thermal protection on the lunar surface camera. Flight plan called for 11 telecasts during the mission. Contained in the ALSEP were a Charged Particle Lunar Environment Experiment (CPLEE) to measure particle energies of protons and electrons reaching the lunar surface from the sun.

The CPLEE detector package contained two spectrometers providing data on the direction of the incoming flux. The Lunar Atmosphere Detector (LAD) utilized a cold cathode ionization gauge to measure the density of neutral particles at the lunar surface and the variations in density associated with lunar phase or solar activity. The Lunar Heat Flow Experiment (HFE) was to measure the steady state heat flow from the lunar interior, and consisted of instrument probes (two 20-inch long sections, each containing a gradient sensor bridge, a ring sensor bridge and two heaters), electronics, emplacement tool and the lunar surface drill. The Passive Seismic Experiment (PSE) would measure seismic activity of the moon and obtain information on the physical properties of the lunar crust and interior. The Solar Wind Composition Experiment (SWCE – not part of the ALSEP) would determine the elemental and isotopic composition of the noble gases in the solar wind. The ALSEP Dust Detector would detect the presence of dust or debris impinging on the ALSEP. A duplicate of the Apollo XII SNAP-27 (Systems for Nuclear Auxiliary Power) radioisotope thermoelectric generator, would provide power for the Apollo XIII ALSEP. Fueled with Plutonium 238, SNAP-27 weighs 43.5 pounds and produces at least 63 watts of power. Apollo XIII photographic equipment consisted of two 70mm Hasselblad data cameras fitted with 60mm Zeiss metric lenses, a 16mm motion picture camera with a 10mm lens, and a Kodak closeup stereo camera for high resolution lunar surface photos. The 65-pound Lunar Topographic Camera, flown for the first time on Apollo XIII, had an 18-inch focal length, f/4 lens. The crew included Spacecraft Commander James A. Lovell, 42, U.S. Navy captain; Command Module Pilot John L. Swigert, Jr., 38, a civilian; and Lunar Module Pilot Fred W. Haise, Jr., 36, a civilian.

Project Results* – Apollo XIII was successfully launched on schedule from Launch Complex 39A, Kennedy Space Center, Fla., April 11, 1970. The S-IVB/instrument unit (IU)/spacecraft combination was inserted into an Earth parking orbit with an apogee of 100.2 nm and a perigee of 98.0 nm (planned was a 100 nm circular orbit). During second stage boost the center engine of the S-II stage cut off about 132 seconds early, causing the remaining four engines to burn approximately 34 seconds longer than predicted. Space vehicle velocity after S-II boost was 223 feet per second lower than planned. As a result, the S-IVB orbital insertion burn was within about 1.2 fps of planned. Total launch vehicle burn time was about 44 seconds longer than predicted.

*Information from Official NASA Report of Apollo XIII Accident Review Board, June 15, 1970.



Tracking ship "USS Vanguard" during launch of Apollo XIII. The floating tracking station supported the mission "down range" from Cape Kennedy.

After orbital insertion, the second S-IVB burn was initiated on schedule for Translunar injection (TLI). All major systems operated satisfactorily and conditions were nominal for a free-return circumlunar trajectory. The CSM separated from the LM/IU/S-IVB. On-board television was initiated for about 72 minutes. The Service Module (SM) reaction control system propellant usage for the separation, transposition, docking and ejection was nominal.

The S-IVB APS evasive maneuver by an 80 second APS ullage burn and the liquid oxygen dump was successfully completed. The first S-IVB APS burn for lunar target point impact was initiated for 217 seconds, producing a differential velocity of approximately 28 fps. The S-IVB/IU impacted the lunar surface at 2.4°S, 27.9°W, and the seismometer deployed during the Apollo XII mission successfully detected the impact. The actual impact point was 74 nm (targeted for 125 nm) from the seismometer.

The accuracy of the TLI maneuver was such that spacecraft midcourse correction No. 1 (MCC-1) was not required. MCC-2 was performed as planned, placing the spacecraft on the desired, non-free-return circumlunar trajectory with a predicted closest approach to the moon of 62 nm. All Service Propulsion System (SPS) burn parameters were normal. Quality television

coverage of the preparation and performance of MCC-2 was received for 49 minutes.

Approximately 55 hours 55 minutes into the mission, the crew reported an undervoltage alarm on the CSM main bus B. Pressure was rapidly lost in SM oxygen tank no. 2 and fuel cells 1 and 3 current dropped to zero due to loss of their oxygen supply. A decision was made to abort the mission. The increased load on fuel cell 2 and decaying pressure in the remaining oxygen tank led to the decision to activate the LM, power down the CSM, and use the LM systems for life support.

Post-mission analysis by the Apollo XIII Accident Review Board determined that a short circuit had ignited electrical insulation in spacecraft oxygen tank no. 2, causing failure of the tank, subsequent loss of electrical power and abort of the mission approximately 205,000 miles from Earth. A special detanking procedure applied to the no. 2 oxygen tank prior to launch "probably resulted in major damage to the wiring insulation in the tank."

At 61 hours 30 minutes into the mission, a 38 fps midcourse maneuver (MCC-4) was performed by the LM Descent Propulsion System (DPS) to place the spacecraft in a free-return trajectory on which the CM would nominally land in the Indian Ocean south of Mauritius. At pericynthion plus 2 hours, a LM DPS maneuver was performed to shorten the return trip time and move the Earth landing point. The 263.4-second burn produced a differential velocity of 860.5 fps and resulted in an initial predicted Earth landing point in the Mid-Pacific Ocean 142 hours 53 minutes into the mission. Both LM guidance systems were powered up and the primary system was used for this maneuver. Passive thermal control was established and the LM was powered down to conserve consumables; only the LM environmental control system (ECS) and communications and telemetry systems were kept powered up.

The LM DSPS was used to perform MCC-5. The 15-second burn (at 10 per cent throttle) produced a velocity change of about 7.8 fps, raising the entry flight path angle to -6.52°. Due to the unusual spacecraft configuration, new procedures for entry were developed and verified in ground-based simulations. The resulting timeline called for a final mid-course correction (MCC-7) at entry interface (EI) minus 5 hours, jettison of the SM at EI-4.5 hours, then jettison of the LM at EI-1 hour prior to the normal atmosphere entry by the CM.

MCC-7 was a 22.4-second LM RCS maneuver resulting in a predicted entry flight path angle of -6.49°. The crew viewed and photographed the jettisoned SM and reported that an entire panel was missing near the S-band high-gain antenna and a great deal of debris was hanging out. The CM was powered up and then the LM was jettisoned.

Landing was in the Mid-Pacific Ocean, approximately 21°40′S, 165°22′W, on April 17, about 3.5 nm from the prime recovery ship USS Iwo Jima.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell, CM and SM spacecraft prime contractor; SPS, Aerojet-General, principal and subcontractors; AVCO, ablative heat shield; Collins, communication and data subsystems; Garrett, environmental control system; Grumman, LM spacecraft prime contractor; General Motors (manufacturing) and MIT (technical management), primary guidance and navigation system; North American Rockwell, ascent engine; RCA, communications subsystems and radar and control electronics; TRW, descent engines and abort guidance system; Hamilton-Standard, astronauts' portable life support systems; ILC Industries, space suits; Bendix, Apollo Lunar Surface Experiments Package; IBM, IU prime contractor; Boeing, Apollo-Saturn V technical integration and evaluation; GE, Apollo checkout equipment, related engineering design, quality management, and engineering support; TRW, mission trajectory control and spacecraft systems analysis; NASA Marshall Space Flight Center, launch vehicle management; Boeing, first stage prime contractor; North American Rockwell, second stage; McDonnell Douglas, third stage; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, Manned Space Flight Network management.

Key Spacecraft Personnel		Affiliation
PM	R. Petrone	NASA Headquarters
PS	M. W. Molloy	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Photography	PI	Mapping Sciences Laboratory	NASA-JSC
Window Meteoroid	PI	B. G. Cour-Palais	NASA-JSC
	OI	M. L. Brown	Lockheed Electronics
	OI	D. S. McKay	NASA-JSC
Passive Seismic Experiment	PI	Unknown	Unknown
Heat Flow Experiment	PI	Unknown	Unknown
Charged Particle Detectors	PI	Unknown	Unknown
Cold Cathode Ion Gauge	PI	Unknown	Unknown
Dust Detector	PI	Unknown	Unknown
Field Geology Experiment	PI	Unknown	Unknown

SKYNET II

Launch Vehicle – Thrust Augmented Thor-Delta. Same as OSO VII.

Spacecraft Description – A cylinder 54 inches in diameter, 32 inches high. A mechanically despun directionalized antenna projects from the top. An exhaust nozzle for the solid-propellant apogee motor, used for insertion into synchronous orbit, protrudes from the bottom, creating a total height of 62 inches. The body was covered with 7,236 negative-on-positive solar cells. Spacecraft is spin-stabilized at 90 rpm. In orbit weight: 285 pounds.

Project Objectives – Similar to Skynet I. To maintain communications between United Kingdom terminals and sea/land-based military locations.

Spacecraft Payload – An X-band repeater with two channels for receiving, frequency translating, amplifying and retransmitting voice, wide-band data, telegraph and facsimile data; two three-watt travelling wave tube final amplifiers; two 16-cell 6 ampere-hour capacity nickel cadmium batteries; programming and sequencing equipment; command and telemetry subsystems; and duplicated ground-commanded satellite electronics.

Project Results – Skynet II was launched August 19, 1970, from Cape Kennedy, Fla. Telemetry terminated following apogee motor failure. Spacecraft was left in its transfer orbit of 168 by 22,410 miles.

Major Participants – United Kingdom's Ministry of Defence and Ministry of Technology, program management; USAF Space and Missile Systems Organization, spacecraft management; Aerospace Corp., systems engineering and technical direction; Philco-Ford, spacecraft prime contractor; McDonnell Douglas, launch vehicle prime contractor.

RADIATION METEOROID SATELLITE (RMS) OFO I

Launch Vehicle – Scout B. Same as Explorer XLII.

Spacecraft Description – OFO: Structure was 30 inches in diameter and 47 inches long. A lower, octagonally-shaped section housed spacecraft electronics and an upper section, with a heat control shield covering a water-filled centrifuge, housed the Frog Otolith Experiment Package in a truncated cone with a spherical cap. Exterior protuberances included five antennas canted at 45 degrees to support onboard telemetry and command and beacon subsystems. The yoyo despin assembly was located around the girth of the spacecraft, and four triple-fold booms were located radially around the spacecraft at 90 degree intervals. Power was provided by battery packs. Weight: 293 pounds.

RM: The Radiation Meteoroid spacecraft consisted of two cylindrical segments mounted around the fourth stage of the launch vehicle which remained attached in orbit. The lower cylinder, 15 inches high, held seven square feet of solar cells to provide 25 watts of power to the spacecraft and its experiments. Power was supplemented by a system of rechargeable batteries. The upper cylinder housed the electronics package and experiments. Weight: 46.3 pounds.

Project Objectives – OFO: Through microelectrodes surgically implanted in the vestibular (inner ear) nerves leading from sensor cells in the otoliths or gravitoreceptors of the frogs' ears, the experiment studied the effects of weightlessness and the response to acceleration of the vestibule of the inner ear which controls balance. Frogs were chosen because of the resemblance of their inner ear structure to that of man. Data from the five-day experiment was being applied in the study of the effects of weightlessness on man during flights in space and in high-speed, high-altitude aircraft.

RM: Demonstration of the feasibility and accuracy of an advanced radiation dosimetry system and in-flight verification of improved instrumentation to measure meteoroid impact, flux, direction and speed. Data was to be applied to the design of radiation and meteoroid safety measures for future manned missions. Radiation experiment data also was to be used to update descriptions of the radiation belts which circle the Earth.

Spacecraft Payload – OFO: Two male bullfrogs, each weighing approximately 0.7 pounds were housed in a water-filled, self-contained centrifuge which supplies the test acceleration. Also in the 91-pound experiment package was the necessary instrumentation to collect and amplify otolith signals, EKG, water temperature and pressure, and general housekeeping data. The experiment package was encased in a pressure-tight container approximately 18 by 18 inches.

RM: The radiation experiment consisted of an advanced dosimetry system (ADS) and three standard ionization chambers. The ADS consisted of a solid state radiation spectrometer and a spectrum-to-dose converter. The spectrometer had multiple viewing angles and its three solid state detectors were

selectively sensitive to electrons and protons. The unit measured electrons with energies ranging from 0.6 to 4 Mev and protons with energies from 10 to several hundred Mev. The converter determined real-time energy absorption. Conventional dose measurements were obtained by three standard ion chambers filled with a mixture of argon and helium. Penetrating radiation ionizes the gas, causing a flow of current that was measured and converted to dose rates for relay to the telemetry system. Each of the two identical meteoroid instruments consisted of two flat meteoroid detection surfaces, or plates, parallel to each other and spaced three inches apart. Each plate was eight inches square and made up of a mosaic of one-inch square thin film capacitors electrically connected in one-by-eight-inch rows. Each capacitor was identified in the electronics for meteoroid impact information. Signals from the outermost plate were used to record meteoroid flux and number of penetrating impacts. Signals from both plates were used to measure meteoroid speed and direction. A meteoroid mass of 10^{-14} gram or larger was required to penetrate the outer plate. Masses greater than 10^{-12} gram penetrated both surfaces to yield speed and direction measurements.

Project Results – OFO and RM were launched November 9, 1970, from Wallops Island and achieved similar orbits of 180 by 315 miles at 37.4 degrees inclination. Data from OFO were received for 6 days. At first, the frogs' otolith frantically signaled the nervous system that a prime reference point for balance – gravity – had been lost. The otolith began to adjust slowly and within three days was sending back signals to Earth that all was normal. This experiment may have given an indication why astronauts have frequently had difficulty in adjusting to weightlessness in the early stages of space flight. This had usually been described as a kind of motion sickness, but could result from the astronauts' otolith attempting to adjust. No attempt was made to recover the frogs. The RM experiments were activated and returned good data during three month mission.

Major Participants – NASA's Office of Advanced Research and Technology and Wallops Station, OFO spacecraft management; Aerojet-General, OFO prime contractor; NASA Ames, OFO experiment management; Johns Hopkins University, experiment contractor; NASA's Office of Advanced Research and Technology and Manned Spacecraft Center, RM spacecraft management; Ling-Temco-Vought, RM prime contractor; Manned Spacecraft Center, experiment investigator; NASA Langley, launch vehicle management; Ling-Temco-Vought, launch vehicle prime contractor.

Experiment	Experiment Personnel	Affiliation
Rm 1, Radiation Dosimetry System	PI R. G. Richmond OI B. J. Farmer	NASA-JSC LTV Research Center
Rm 1, Meteoroid Velocity and Flux	PI W. E. McAllum OI J. H. Johnson	NASA-JSC Grahm Magnetics, Incorporated

OAO – B

Launch Vehicle – Atlas-Centaur, same as Intelsat IV.

Spacecraft Description – Octagonal cylinder 7 feet wide and 10 feet long with two paddle-like solar arrays which gave the vehicle a span of 21 feet. Stabilized with inertial wheels using five star trackers and nine gyros, plus a fine error sensor in the Goddard Experiment Package. Cold gas jets unloaded the wheels to avoid saturation. Pointing accuracies of 1 arc-second were achieved. Atop the cylinder was a large, stovepipe-like sun baffle. Two stabilizer booms extended from the side of the cylinder just below the top, 180 degrees opposed. Solar arrays provided an average 430 watts to the spacecraft and its experiment. Weight: 4,680 pounds.

Project Objectives – Stellar observations in the UV region, with concentration on "young" stars to investigate their temperatures and evolution; observation of stars believed to be in the process of evolution; investigation of interstellar dust; study of Quasar 3C273.

Spacecraft Payload – Goddard Experiment Package, a 38-inch Cassegrain telescope operating in the range of 1,100 – 4,267 Å with resolutions from 2 – 64 Å and pointing accuracy of 1 arc-second. Telescope accuracies in the UV range exceed those of OAO II by a factor of 5, and the GEP could observe stars eight times fainter. A star-pointing fine error sensor drove the spacecraft's stabilization and attitude control subsystems and sent signals to the GEP telescope to begin data gathering.

Project Results – OAO-B was launched aboard an Atlas-Centaur from Cape Kennedy November 30, 1970. The 2,400-pound Centaur nose fairing failed to separate, making it impossible for the spacecraft to achieve orbital velocity. Spacecraft and shroud burned in the atmosphere over Africa or the Indian Ocean.

Major Participants – NASA Goddard Space Flight Center, spacecraft management; Grumman Aerospace Corp., spacecraft prime contractor; NASA-Goddard, experiment management; Kollsman Instrument Corp., experiment prime contractor; NASA Lewis Research Center, launch vehicle management; General Dynamics, launch vehicle prime contractor.

ITOS – A
NOAA – I

Launch Vehicle – Delta N. Same configuration as for ITOS-I.

Spacecraft Description – Same as ITOS-I.

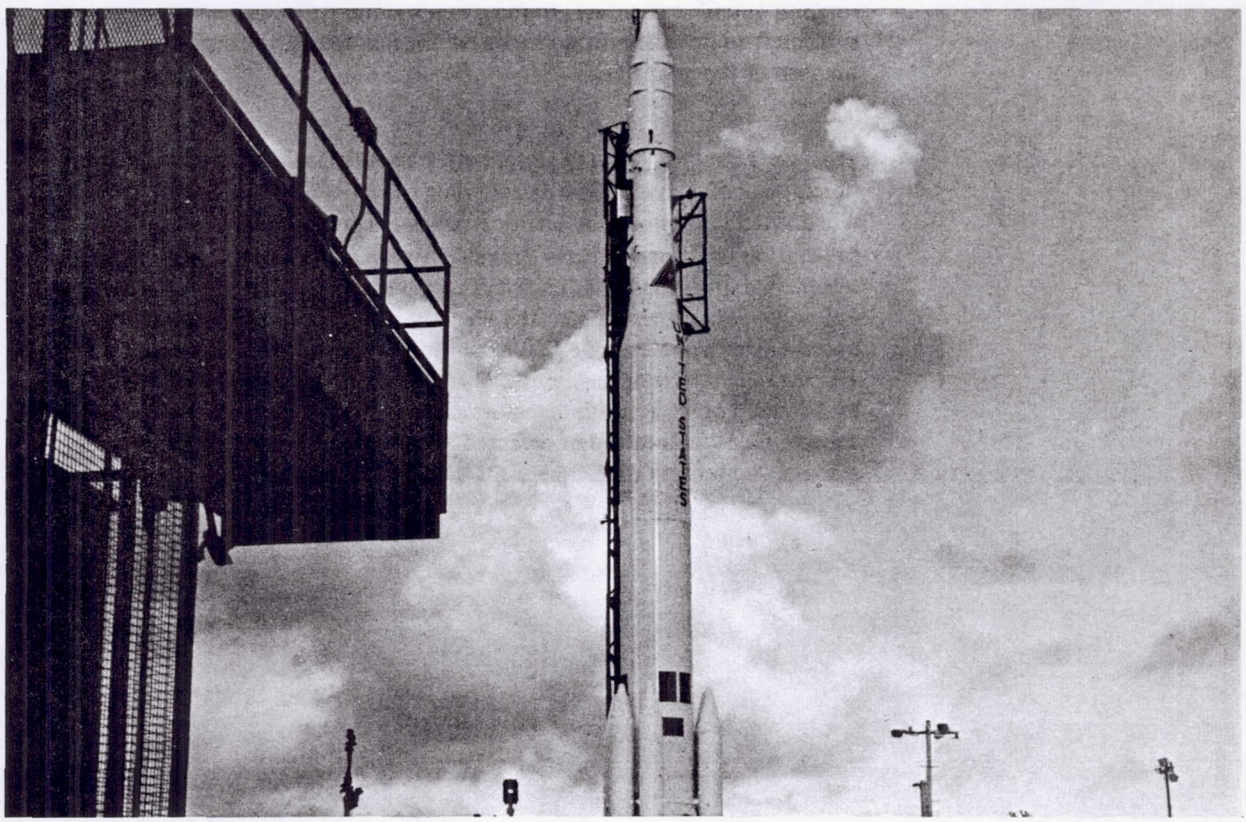
Project Objectives – Augmentation of United States' satellite world-wide weather observation capabilities for the National Weather Service of the National Oceanic and Atmospheric Administration (NOAA).

Spacecraft Payload – Same as ITOS-I.

Spacecraft Results – ITOS-A/NOAA-I was launched December 11, 1970, from Space Launch Complex 2-West, NASA Western Test Range, Vandenberg AFB, Calif. Spacecraft was placed in an 888 by 915 mile orbit, with an inclination of 101.94 degrees and a period of 114.93 minutes. No systems malfunctions were reported.

Major Participants – NASA Goddard Space Flight Center, ITOS1 spacecraft management; RCA, spacecraft prime contractor; Project Australis, University of Melbourne. ESSA functions were assumed by the newly created NOAA.

The eighty-first Delta Vehicle carried the first NOAA-funded operational Spacecraft, the ITOS-A/NOAA-I, launched December 11, 1970.



1970

SAS – A (EXPLORER XLII)

Launch Vehicle – Solid propellant Scout: 101,000-pound thrust Algol II first stage, 61,000-pound thrust Castor II second stage, 21,000-pound thrust Antares II third stage, and the Altair III fourth stage. Height: 73 feet. Vehicle weight at liftoff: 40,000 pounds.

Spacecraft Description – Main structure was a drum 2 feet in diameter and 2 feet high, housing basic spacecraft systems. Mounted on top of drum was the 140-pound X-ray experiment, approximately 13 feet high and similar in appearance to the automobile radiators of the early 1900's. Four solar arrays, approximately 1 by 5½ feet, were spaced windmill-like at 90-degree intervals around the drum and deployed in orbit to provide 27 watts of power to spacecraft and its experiment. Spacecraft was spin-stabilized at 5 rpm by a gyroscope, an electromagnet which aligns itself with the Earth's north-south magnetic field, and a nutation damper. Spacecraft weight: 315 pounds.

Project Objectives – Catalog celestial X-ray sources within and outside the Milky Way by systematic scanning of the celestial sphere in the energy range from 2,000 to 20,000 electron volts. Measurements of known and newly-discovered X-ray sources include position, strength, spectral composition and time variation from minutes to months. Accuracy for location of the stronger sources is one arc-minute, and for weaker sources; 15 arc-minutes. Data from Explorer XLII was correlated with radio and optical astronomy findings obtained from the ground, from sounding rockets, and from other spacecraft to provide astronomers new information on the high-energy phenomena of the galaxy.

Spacecraft Payload – X-ray astronomy instrument was an advanced version of experiments flown earlier on sounding rockets. The 140-pound package was divided into essentially identical halves, each independent of the other. In addition to the redundancy provided by the dual system, each side contained redundant elements. Each half contained an X-ray detector, a mechanical collimator which defined the viewing direction, and operating and processing electronics. For high resolution, one collimator provided a 1° by 10° field of view. For high sensitivity, the other collimator provided a 10° by 10° field of view. Both detectors scanned the same path in the celestial sphere. Celestial location of detected X-ray sources was determined using star and sun sensors aligned with the collimators.

Project Results – SAS-A (Explorer XLII) was launched December 12, 1970, from the Italian-operated San Marco launch platform in the Indian Ocean off the coast of Kenya in East Africa. It was the first American satellite to be launched by another country. The launch was the first under the terms of an agreement between NASA and the University of Rome whereby NASA provided the satellite and launch vehicle, and the university's Aerospace Research Center provided assembly, checkout and launch services. The launch date was Independence Day in Kenya, and NASA and the University of Rome dedicated the satellite to Kenya in recognition of that country's cooperative role in establishing the San Marco launch platform. Once in its 324 by 349-mile near-equatorial orbit, the satellite was also named Uhuru, the Swahili word for freedom.

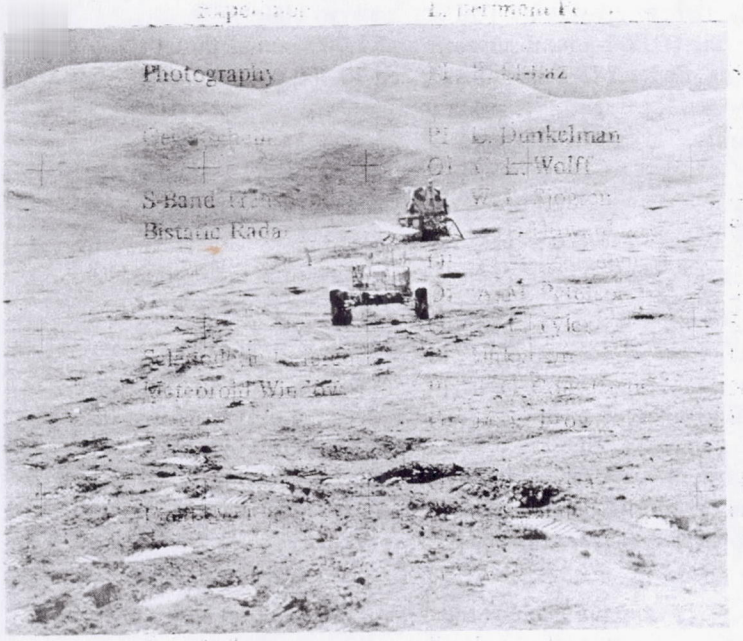
Major Participants – NASA Goddard Space Flight Center, spacecraft management; Johns Hopkins University, spacecraft prime contractor; American Science and Engineering Co., Inc., experimenter; NASA Langley Research Center, launch vehicle management; Ling-Temco-Vought Aerospace Corp., launch vehicle prime contractor; University of Rome Aerospace Research Center, final checkout and launch services.

Key Spacecraft Personnel		Affiliation
PM	M. R. Townsend	NASA-GSFC
PS	C. E. Fichtel	NASA-GSFC
MG	J. R. Holtz	NASA Headquarters
SC	N. G. Roman	NASA Headquarters

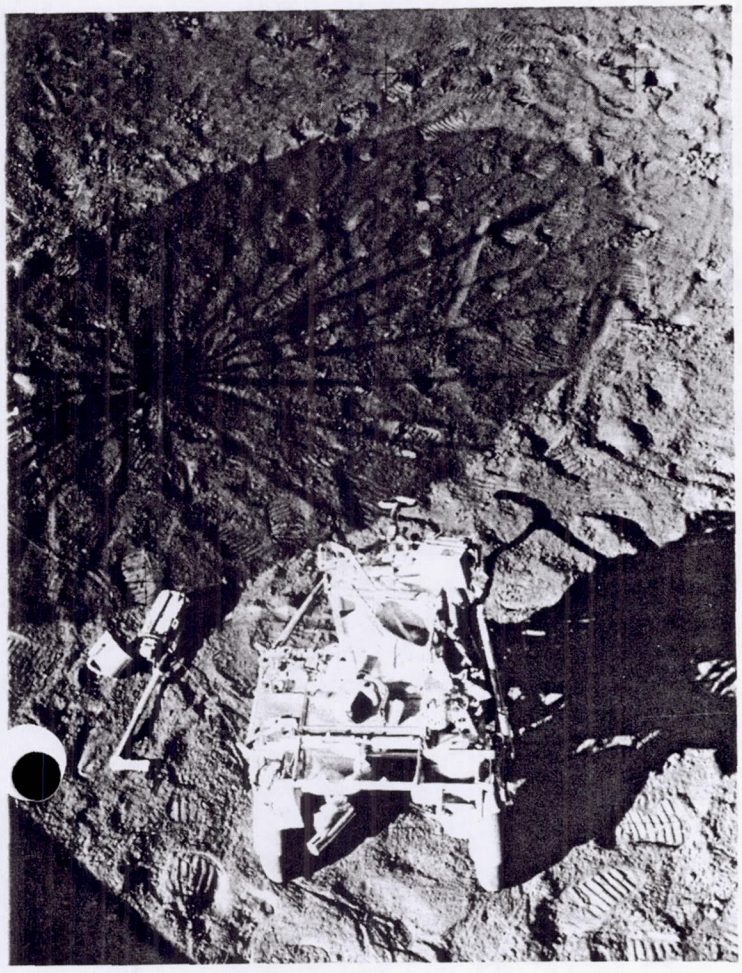
Experiment	Experiment Personnel		Affiliation
X-Ray All Sky Survey	PI	R. Giacconi	Harvard College Observatory
	OI	F. M. Kellogg	Harvard College Observatory
	OI	H. Gorsky	Harvard College Observatory
	OI	H. Tananbaum	Smithsonian Astrophysical Observatory
	CO	G. Austin	AS+E, Incorporated

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1971



(Top) Lunar Rover and Lunar Module "Falcon" are deployed on Hadley-Apennine site where Apollo XV astronauts touched down at 6:16 p.m. EDT, July 30, 1971.
(Below) Lunar rover on the Moon as viewed from the lunar lander.





Astronaut David R. Scott on slope of Hadley Delta with rover in background.

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INTELSAT IV Flight 2 and INTELSAT IV Flight 3

Launch Vehicle – Atlas Centaur: Atlas SLV-3C first stage with 402,000 pounds thrust including 60,000-pound sustainer and 1,000-pound thrust vernier control system. Centaur D-1 second stage had 30,000 pounds thrust. Solid propellant SVM-4A third stage (apogee motor mounted in spacecraft) had 10,000 pounds thrust. Height: 132 feet.

Spacecraft Description – Cylinder: 94 inches in diameter, 111 inches high. Total spacecraft height was 17 feet, 6 inches. Solar cells (n on p) form array covering basic drum providing 570 watts power at beginning of life. Spin rate was approximately 60 rpm. Weight at launch: 3,100 pounds; in orbit, 1,559 pounds. Nominal life estimated seven years.

Project Objectives – This fourth-generation satellite increased the capacity of Intelsat's global commercial communications network. Each Intelsat IV could carry a maximum of 9,000 telephone calls or 12 color television broadcasts, with projected circuit mix for voice, video, data and facsimile transmission expected to total about 5,000 channels.

Spacecraft Payload – The communications subsystem, mounted on a mechanically despun platform, included six antennas: two 50-inch dishes for spotbeam transmission to Earth, and a cluster of four conical horn antennas, two for widebeam transmission to Earth and two for receiving from Earth. Antennas were connected to a 12-channel microwave repeater system which provides power amplification for each channel individually. Each 50-inch dish antenna could be directed to almost any point on Earth within line of sight of the satellite. Antenna beamwidth was about 4 degrees. The antennas were steerable in increments of less than 0.1 degree. The global transmit and receive antennas were mounted vertical to the spin axis and directly behind the twin dish antennas, and had a beamwidth of 17 degrees to provide broader coverage. Effective isotropic radiated power at beam center was 37.7 dbw for spotbeam and 22 dbw for widebeam. The communications subsystem received at 5932 to 6418 MHz and transmitted at 3707 to 4192 MHz with a total useable bandwidth of 432 MHz over 12 channels. The satellite also carried omnidirectional command-receive and telemetry-transmit antennas. Station keeping was by two redundant hydrazine half systems, each with two axial, radial and spinup jets.

Project Results – Flight II was launched from Cape Kennedy, Fla., January 25, 1971, into synchronous orbit and positioned over the Atlantic at 24.5° W. Long. Commercial service began on March 26, 1971. Flight III was launched December 19, 1971, into synchronous orbit and positioned over the Atlantic at 19.5°W. Long. Commercial service was scheduled for early 1972. Flight I was scheduled for launch later in the program.

Major Participants – Communications Satellite Corp., spacecraft management; Hughes Aircraft, spacecraft prime contractor; NASA Lewis, launch vehicle management; General Dynamics, launch vehicle prime contractor; Aerojet-General, apogee motor. Twelve major suppliers from 10 countries make up the international contractor team.

APOLLO XIV

Launch Vehicle – Saturn V (AS 509), essentially the same launch vehicle as used on Apollo XIII with exception of three major changes in the S-II second stage: a helium gas accumulator in the liquid oxygen (LOX) line of the center engine to lower the frequency of the LOX line and prevent unusually high oscillations ("Pogo" effect); a backup cutoff device to shut down the center engine in the event of pogo instability; and a simplified 2-position pneumatically actuated propellant utilization valve on each of the 5 J-2 engines, replacing a motor driven, servo-controlled valve.

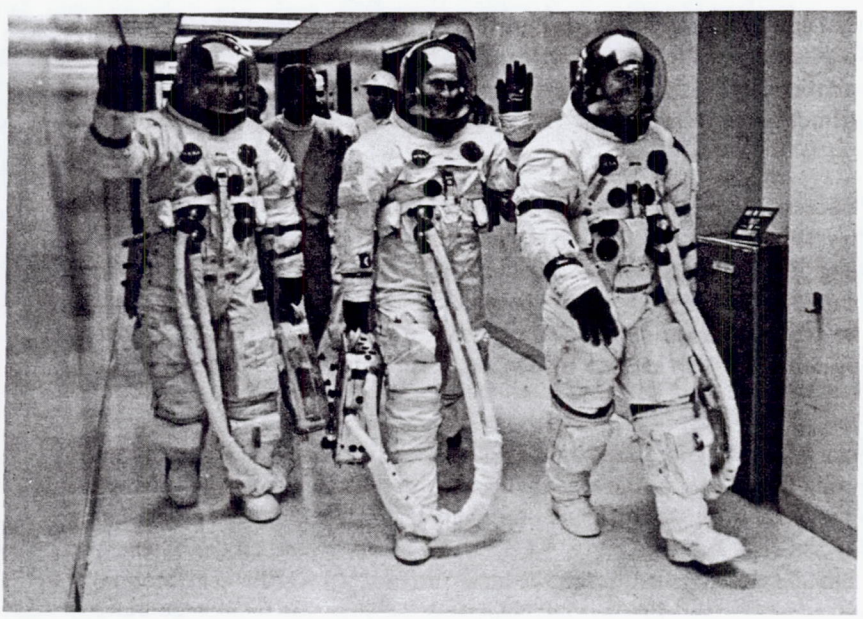
Spacecraft Description – Spacecraft combination exceeded Apollo XIII weight by 994 pounds, much of which resulted from modifications in the CSM, prompted by the Apollo XIII accident. Apollo XIV CM 110 (Kitty Hawk) had a launch weight of 12,694 pounds; SM, 51,744; SLA, 4,061; and LM 8 (Antares), 33,680. Major changes to the CSM included addition of a third cryogenic oxygen tank in the SM, addition of an auxiliary battery in the SM as a backup in case of fuel cell failure, removal of destratification fans in the cryogenic oxygen tanks, and removal of thermostatic switches from the oxygen tank heater circuits. Provision for stowage of an emergency 5-gallon supply of drinking water was also made. As a result of the Apollo XIII accident, wiring provisions were made in the LM ascent state to permit power transfer from LM to CM after LM descent stage separation. "Dry" weight of the LM totaled 9,407 pounds; propellant (RCS, DPS, APS) weight was 24,273.

Project Objectives – Lunar surface science centered around deployment of the Apollo Lunar Surface Scientific Experiment Package (ALSEP), lunar field geology investigations, collection of samples of surface materials for return to Earth, deployment of other scientific instruments not part of ALSEP, orbital science involving high resolution photography of candidate future landing sites, photography of deep-space phenomena such as Zodiacal light and Gegenschein, communications tests using S-band and VHF signals to determine reflective properties of the lunar surface, tests to determine variations in S-band signals, and photography of surface details from 60 nm altitude; engineering/operational evaluations of hardware and techniques.

Spacecraft Payload – The ALSEP Array C contained five experiments: Passive Seismic Experiment (PSE) to measure seismic activity of the moon and to gather and relay to Earth information about physical properties of the lunar crust and interior; Active Seismic Experiment (ASE) to gather data on the physical structure and bearing strength of the lunar surface by measuring seismic waves created by the detonation of small explosive charges; Suprathermal Ion Detector Experiment (SIDE) to measure flux, composition, energy and velocity of low-energy positive ions and the high-energy solar wind flux of positive ions; Cold Cathode Ion Gauge (CCIG) for measuring the density of the lunar ambient atmosphere and any variation with time or solar activity such an atmosphere may have; Charged Particle Lunar Environment Experiment (CPLEE) to measure particle energies of solar protons and electrons that reach the lunar surface. An ALSEP central station served as a power-distribution and data-handling point for experiments and

included a data subsystem, helical antenna, experiment electronics, power conditioning unit and dust detector. Two independent experiments were also included: the Laser Ranging Retro-Reflector (LRRR) to permit long-term measurement of the Earth-moon distance by acting as a passive target for laser beams directed from observatories on Earth, and a Lunar Portable Magnetometer (LPM) used by the crew during the second EVA for measuring variations in the lunar magnetic field at several points in the geology traverse. Apollo lunar hand tools for use in field geology activities included a special high vacuum retention environmental container for lunar samples, an extension handle for use with several tools, six core tubes, large and small scoops, sampling hammer, tongs, a brush/scriber/hand lens, spring scale, instrument staff, gnomon (used as a photographic reference to indicate local vertical), a color chart, 35 field sample bags, a trenching tool, and a modular equipment transporter (MET), and a two-wheeled, two-legged cart used during EVAs to carry tools, experiments and lunar samples. Apollo XIV carried essentially the same photographic equipment (with the exception of multispectral cameras) and television cameras as Apollo XIII. To facilitate recognition of crewmen in photographs and TV transmissions from the lunar surface, the Apollo commander was identified by red stripes around the elbows and knees of his pressure suit. Four zero-gravity inflight demonstrations were aboard the CM and conducted during the return to Earth phase of the mission. The demonstrations were Electrophoretic Separation, Heat Flow and Convection, Liquid Transfer, and Composite Casting, and were designed to illustrate the utilization of the unique conditions of zero-gravity. These simple tests provided information useful in establishing design requirements for future experiments in Materials Science and Manufacturing in the space program. The crew included Spacecraft Commander Alan B. Shepard, Jr., a Navy captain; Command Module Pilot Stuart A. Roosa, an Air Force major; and Lunar Module Pilot Edgar D. Mitchell, a Navy commander.

The Apollo XIV team gets ready to take off.





Successful Pacific Ocean recovery of astronauts Alan B. Shepard, Jr., Stuart A. Roosa, and Edgar D. Mitchell.

Project Results – Apollo XIV was launched at 4:03 p.m. EST, January 31, 1971, from Launch Complex 39 at Cape Kennedy, Fla. Approximately 3:41 ground elapsed time (GET) difficulties were experienced in docking with Lunar Module, and six attempts were required before a "hard dock" was achieved. In-flight televised inspection of the docking mechanism revealed no apparent reason for the malfunction and the system appeared to be functioning normally. Prior to Powered Descent Initiation (PDI) for Antares' landing, a short in the LM computer abort switch was discovered which could have triggered an undesired abort during the LM's descent. On February 5, Antares made the most precise landing to date, approximately 87 feet from the targeted landing point. Landing point coordinates were 3° 40′27″S, 17°27′58″W, midway between Doublet and Triplet craters, in the hilly uplands of the Fra Mauro crater (about 110 miles east of the Apollo XII landing site). Due to communications system problems, the first period of Extra Vehicular Activity began almost one hour later than scheduled with Spacecraft Commander Alan Shepard setting foot on the lunar surface at 114:31 hours GET. The first of the two EVA periods included ALSEP deployment and lasted 4 hours, 49 minutes. The second EVA on February 6 began when the LM egress hatch was opened at 4:15 a.m. EST. During this EVA, Shepard and Mitchell moved more than half a mile from their LM, conducting selenological investigations, collected samples, and attempted to reach the rim of Cone Crater, approximately 300 feet above the landing site. NASA personnel monitoring the EVA estimate that the two astronauts were within 50-75 meters of the crater rim when they were advised by Mission Control to collect samples at that spot and begin their traverse back to the LM. The second EVA lasted 4:35 hours, resulting in a new mark for EVA time by a lunar landing crew: 9 hours, 24 minutes. Shepard set a new distance-traveled record on the lunar surface: approximately 9,000 feet. During the two traverses, the astronauts collected 94 pounds of rocks and soil for return to Earth (samples were scheduled to go to 187 scientific

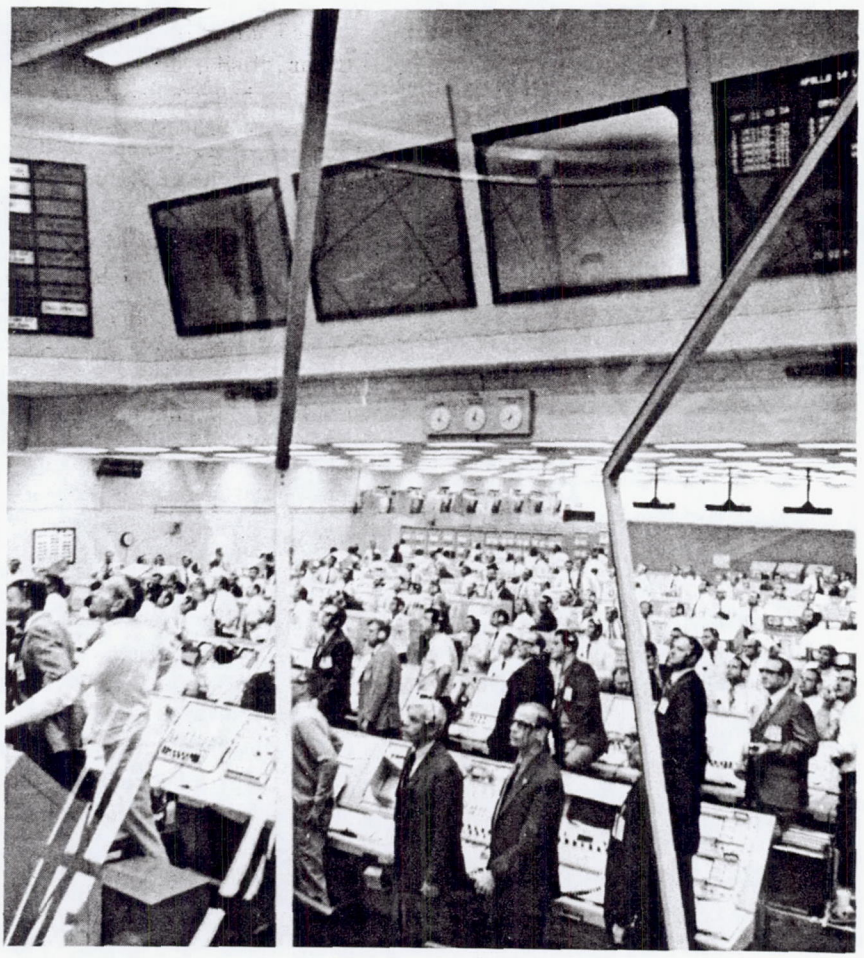
teams in the U.S. and 14 foreign countries for study and analysis). Orbital science activities were conducted by Stuart Roosa during the lunar surface activities period and he experienced some difficulties with the high-resolution, motion-compensating Hycon Lunar Topographic Camera while attempting to photograph the Descartes area (Apollo XVI landing site). Antares' lift-off from the lunar surface took place precisely on schedule; rendezvous and docking were only 2 minutes later than scheduled. The CM "Kitty Hawk" splashed down safely in the Pacific Ocean at 4:05 p.m. EST, February 9, 1971, exactly 9 days and 2 minutes after launch. Actual landing point was only 1.02 nm off its targeted point and four miles from the prime recovery ship, the USS New Orleans. Coordinates were 27°2′S, 172°40′W, about 765 nm south of American Samoa. Mission duration from liftoff to splashdown was 216 hours, 2 minutes.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell, CM and SM spacecraft prime contractor; SPS, Aerojet-General, principal and subcontractors; AVCO, ablative heat shield; Collins, communication and data subsystems; Garrett, environmental control system; Grumman, LM spacecraft prime contractor; General Motors (manufacturing) and MIT (technical management), primary guidance and navigation system; North American Rockwell, ascent engine; RCA, communications subsystems and radar and control electronics; TRW, descent engines and abort guidance system; Hamilton-Standard, astronauts' portable life support systems; ILC Industries, space suits; Bendix, Apollo Lunar Surface Experiments Package; IBM, IU prime contractor; Boeing, Apollo-Saturn V technical integration and evaluation; GE, Apollo checkout equipment, related engineering design, quality management, and engineering support; TRW, mission trajectory control and spacecraft systems analysis; NASA Marshall Space Flight Center, launch vehicle management; Boeing, first stage prime contractor; North American Rockwell, second stage; McDonnell Douglas, third stage; NASA Kennedy Space Center, launch operations; NASA Goddard Space Flight Center, Manned Space Flight Network management.

Key Spacecraft Personnel	Affiliation
Apollo XIV	
PM R. Petrone	NASA Headquarters
Lunar Excursion Module	
MG F. I. Roberson	NASA Headquarters
SC J. B. Hanley	NASA Headquarters
PM W. F. Eichelman	NASA-JSC

Experiment	Experiment Personnel		Affiliation
Photography	PI	F. El-Baz	Smithsonian Institution
Gegenschein	PI	L. Dunkelman	NASA-GSFC
	OI	C. L. Wolff	NASA-GSFC
S-Band Transponder	PI	W. L. Sjogren	NASA-JPL
Bistatic Radar	PI	H. T. Howard	Stanford University
	OI	V. R. Eshleman	Stanford University
	OI	A. M. Peterson	Stanford University
	OI	G. L. Tyler	Stanford University
Selenodetic Reference	PI	Unknown	Unknown
Meteoroid Window	PI	B. G. Cour-Palais	NASA-JSC
	OI	M. L. Brown	Lockheed Electronics
	OI	D. S. McKay	NASA-JSC
Field Geology	PI	G. Swann	U.S. Geological Survey
	OI	W. R. Muehlberger	U.S. Geological Survey
Soil Mechanics	PI	J. K. Mitchell	University of California, Berkeley
	OI	D. Carrier	NASA-JSC
	OI	N. Costes	NASA-JSC
	OI	L. G. Bromwell	Massachusetts Institute of Technology
Solar Wind Composition	PI	J. Geiss	University of Berne
	OI	P. X. Eberhardt	University of Berne
	OI	P. Signer	Federal Institute of Technology
Passive Seismic Experiment	PI	G. V. Latham	University of Texas, Galveston
	OI	W. M. Ewing	
	OI	F. Press	Massachusetts Institute of Technology
	OI	G. H. Sutton	University of Hawaii
Active Seismic Experiment	PI	R. L. Kovach	Stanford University
	OI	J. S. Watkins	University of Texas, Galveston
Suprathermal Ion	OI	F. C. Michel	Rice University
	PI	J. W. Freeman	Rice University
Cold Cathode Ion Gauge	PI	F. S. Johnson	University of Texas, Dallas
	OI	D. E. Evans	Unknown
Charged Particle Detectors	PI	B. J. O'Brien	Department of Environmental Protection
	OI	D. L. Reasoner	NASA-MSFC

Experiment	Experiment Personnel	Affiliation
Laser Retro Reflector	PI J. Faller	University of Colorado
Portable Magnetometer	PI P. Dyal	NASA-ARC
	OI C. P. Sonett	University of Arizona
	OI R. L. Dubois	University of Oklahoma
	OI G. M. Simmons	Massachusetts Institute of Technology
S-Band Transponders (S-164)	PI W. L. Sjogren	NASA-JPL
Lunar Dust Detector	PI J. R. Bates	NASA-JSC

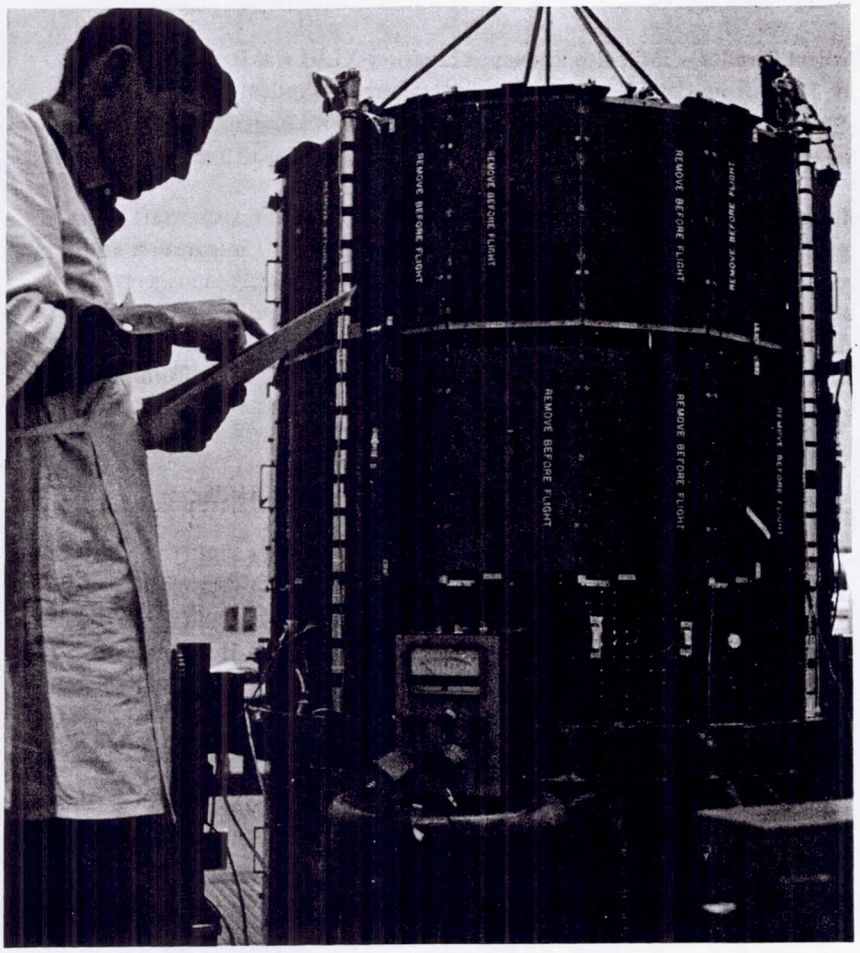


Personnel in Firing Room 2 of the Launch Control Center watch Apollo XIV astronauts lift off from Kennedy Space Center.

IMP-I
EXPLORER XLIII

Launch Vehicle – Delta M-6: Thor liquid first stage augmented by six 50,000-pound thrust solid strap-ons. Three of the strap-ons ignite at liftoff, and three ignite approximately 31 seconds later to provide additional burn time. Total first stage thrust: 325,000 pounds. Restartable Delta second stage had 7,700 pounds thrust. TE-364-3 third stage had 9,500 pounds thrust. Height: 106 feet.

Spacecraft Description – Main structure was a 16-sided drum, 6 feet high and 4½ feet in diameter. Upper portion of drum contained an aluminum honeycomb shelf on which the science instrumentation and spacecraft electronic equipment are mounted. Lower portion had an 18-inch thrust tube to accommodate the third stage motor. Three solar arrays ringed the outside of the drum to provide 110 watts of power, and were supplemented by a 12-pound package of silver-cadmium batteries. Appendages included two 12-foot booms carrying sensors and two 5-foot booms used for attitude control. Six antennas, four 150 feet long and two 20 feet long, deployed in orbit to make electric field measurements and radio astronomy observations. It was spin-stabilized perpendicular to the ecliptic with Freon-14 attitude control system. Total weight was 635 pounds including 215 pounds of experiments. Normal life: one year.



Interplanetary Monitoring Platform (IMP-1) during spacecraft checkout. IMP-1 was the first of a series of second generation satellites to extend man's knowledge of solar-lunar terrestrial relationships. The scientific payload of this project consisted of twelve experiments provided by NASA, Atomic Energy Commission, and universities.

1971

Project Objectives – Investigation of solar and galactic cosmic rays, solar plasma, magnetic and electrical fields, and radio astronomy; continue the energetic particles studies and solar flare monitoring program of earlier IMP missions; study the interplanetary magnetic field and its dynamic relationship with the flow of particles from the sun; study low-frequency radio waves from the Earth's magnetosphere, the solar corona, and the Milky Way to determine their relationship to the magneto-ionic properties of the solar system and the galaxy; and study the Earth's electric field from interplanetary space.

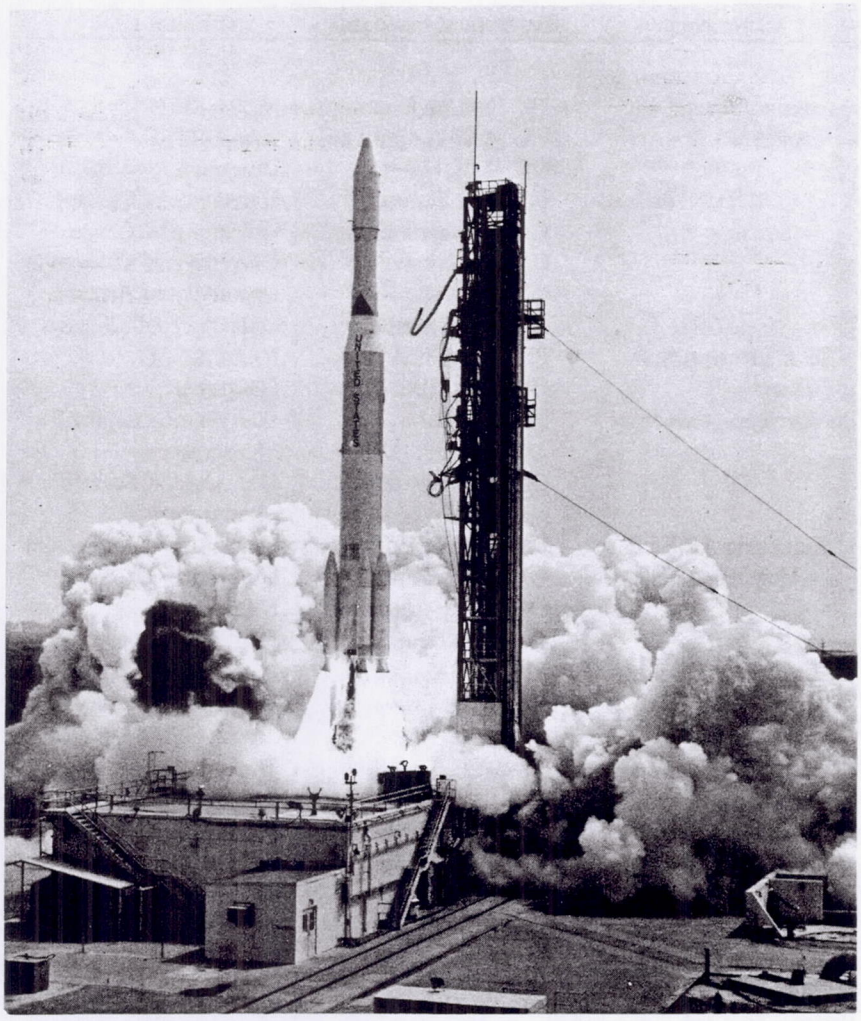
Spacecraft Payload – One engineering experiment: the first flight test of a new onboard computer, a 12.5-pound general purpose, stored-program device with a one-level indirect addressing capability and a hardware index register. It stored 4,000 bits of information and used 5 watts of power. Twelve science experiments: Cosmic ray telescope detectors, galactic and solar particle composition and spectra detectors, low energy particles detector, energetic particle detector, solar proton detectors, solar and distant magnetosphere electron detectors, Goddard plasma experiment, Los Alamos-Sandia plasma experiment, direct current electric fields meter, alternating current electric and magnetic field experiment, magnetometer, and radio astronomy experiment.

Project Results – IMP, also known as Explorer XLIII was launched March 13, 1971, from Cape Kennedy, Fla., into a highly elliptical orbit of 146 by 122,146 miles. Orbital period was approximately 94 hours and inclination to the equator was 28.75°. Experiments were returning good data.

Major Participants – NASA Goddard Space Flight Center, spacecraft management and fabrication; Aerospace Sciences, spacecraft integration and testing; NASA Goddard Space Flight Center, launch vehicle management; McDonnell Douglas, launch vehicle prime contractor; NASA Goddard Space Flight Center, University of Chicago, University of Iowa, University of California at Berkeley, Johns Hopkins University, University of California at Los Angeles, and University of Maryland, experimenters.

Key Spacecraft Personnel		Affiliation
PM	P. Butler	NASA-GSFC
PS	F. B. McDonald	NASA-GSFC
CO	J. H. Trainor	NASA-GSFC
MG	J. R. Holtz	NASA Headquarters
SC	F. R. Schmerling	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Three Axis Magnetometer	PI	N. F. Ness	NASA-GSFC
	OI	J. B. Seek	NASA-GSFC
	OI	D. H. Fairfield	NASA-GSFC
Direct Current Electric Fields	PI	T. L. Aggson	NASA-GSFC
	OI	J. P. Heppner	NASA-GSFC



At 1:15 a.m. EST, on March 13, 1971, a three-stage Delta launched IMP-1 from the Eastern Test Range, Florida.

Experiment	Experiment Personnel		Affiliation
Iowa Alternate Current Electric + Magnetic Fields	PI	D. A. Gurnett	University of Iowa
	OI	P. J. Kellogg	University of Minnesota
	OI	T. I. Aggson	NASA-GSFC
	OI	J. P. Heppner	NASA-GSFC
Solar Plasma Electric Analyzer	PI	K. W. Ogilvie	NASA-GSFC
Electron + Proton 25EV-50keV	PI	L. A. Frank	University of Iowa
Geiger Mueller Detector Proton + Electrons	PI	K. A. Anderson	University of California, Berkeley
Solar Proton Monitor	PI	C. O. Bostrom	Applied Physics Laboratory
	OI	D. J. Williams	NOAA-ERL
	OI	D. S. Beall	Applied Physics Laboratory

Experiment	Experiment Personnel		Affiliation
Cosmic Rays (E vs De/Dx)	PI	F. B. McDonald	NASA-GSFC
	OI	B. J. Teegarden	NASA-GSFC
	OI	D. E. Hagge	Unknown
Cosmic Rays Nuclear Composition	PI	J. A. Simpson	University of Chicago
	OI	M. Garcia-Munoz	University of Chicago
	OI	S. Verma	University of Chicago
	OI	J. Hsieh	University of Arizona
	OI	G. M. Mason	University of Chicago
Solar Electron Scintillator	PI	T. L. Cline	NASA-GSFC
	OI	K. A. Brunstein	Unknown
Plasma Experiment	PI	S. J. Bame	Los Alamos Scientific Laboratory
	OI	J. R. Asbridge	Los Alamos Scientific Laboratory
Minnesota AC Electric + Magnetic Fields	PI	P. J. Kellogg	University of Minnesota
	OI	D. A. Gurnett	University of Iowa
	OI	T. L. Aggson	NASA-GSFC
	OI	J. P. Heppner	NASA-GSFC
Michigan Radio Astronomy Experiment	PI	F. T. Haddock	University of Michigan
	OI	W. C. Erickson	University of Maryland
	OI	R. G. Stone	NASA-GSFC
UMD/GSFC Radio Astronomy	PI	W. C. Erickson	University of Maryland
	OI	R. G. Stone	NASA-GSFC
GSFC Alternate Current Electric Fields	OI	D. A. Gurnett	University of Iowa
	PI	T. L. Aggson	NASA-GSFC
	OI	J. P. Heppner	NASA-GSFC
	OI	P. J. Kellogg	University of Minnesota
Project AC E+B Fields	PI	D. A. Gurnett	University of Iowa
	OI	T. L. Aggson	
Project AC E+B	PI	D. A. Gurnett	University of Iowa
UMD/GSFC Radio Astronomy	PI	W. C. Erickson	University of Maryland
	OI	R. G. Stone	NASA-GSFC
GSFC Alternate Current Electric Fields	OI	D. A. Gurnett	University of Iowa
	PI	T. L. Aggson	NASA-GSFC
	OI	J. P. Heppner	NASA-GSFC
	OI	P. J. Kellogg	University of Minnesota
Project AC E+B Fields	PI	D. A. Gurnett	University of Iowa
	OI	T. L. Aggson	NASA-GSFC
	OI	J. P. Heppner	NASA-GSFC
	OI	P. J. Kellogg	University of Minnesota
Project Radio Astronomy	PI	W. C. Erickson	University of Maryland
	OI	E. T. Haddock	University of Michigan
	OI	R.G. Stone	NASA-GSFC

ISIS B

Launch Vehicle – Delta E. Same as Explorer XLII.

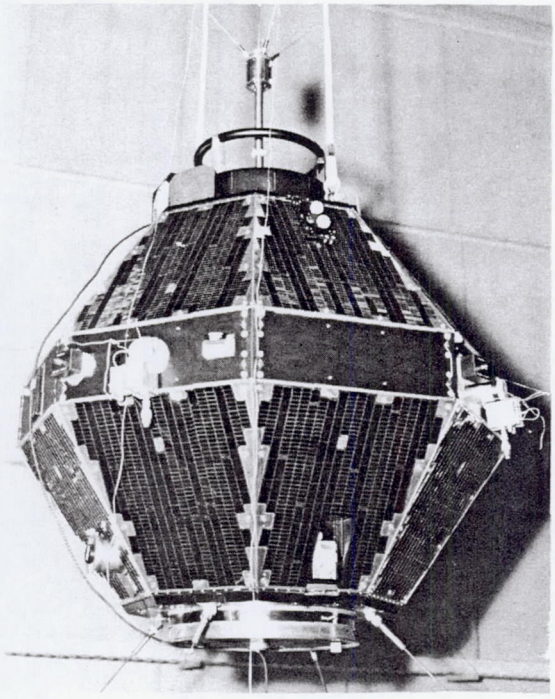
Spacecraft Description – An eight-sided spheroid, 48 inches tall and 50 inches in diameter. Surface covered by 11,000 n-on-p solar cells. Antennas included: two sounder, cross dipole antennas – one 240 feet long and one 61.5 feet long; four telemetry antennas projecting from the base; and quadraloop beacon antennas mounted around the satellite equator. Spin maintenance and spin axis control was by magnetic torquing; attitude sensing by three-axis flux gate magnetometer solar aspect sensor. Weight: 582 pounds.

Project Objectives – Third satellite in a joint Canadian-United States program to study the ionosphere from space. Scientific objectives were to continue the program of measuring daily and seasonal fluctuations in the electron density of the upper ionosphere, study radio and cosmic noise emissions and conduct correlative direct measurements of the energetic particles interacting with the ionosphere.

Spacecraft Payload – Carried 12 ionosphere investigations experiments – eight provided by Canada and four by the United States. Canadian experiments include: swept and fixed frequency ionospheric sounders to map the electron density profile of the ionosphere below the spacecraft; very low frequency receiver and stimulator to observe VLF radio signals of natural origin within the ionosphere and those propagated from ground transmitters, to stimulate and observe VLF resonances produced by a swept frequency oscillator within the spacecraft, and to observe the effects of the surrounding ionosphere plasma on the short sounder antenna; energetic particle detector for direct measurement of electron and proton particle fluxes relative to spacecraft orientation and location using geiger counters, solid state detectors and scintillators; very high frequency beacon for simultaneous transmission of two stable frequency unmodulated 100 milliwatt signals; an experiment to monitor the background noise levels due to galactic, solar and ionospheric sources for correlation with other phenomena; an experiment for direct measurement and mapping intensity of oxygen red-line emission from the aurora and from night, twilight, and day airglow sources; and an experiment for direct measurement and mapping of aurora emissions at two wavelengths of light over the entire auroral zone. U.S. experiments included: soft particle spectrometer for direct measurement of the distribution in energy and direction of negative and positive particles; ion mass spectrometer for direct measurement of the relative abundance of positive ions of mass numbers; cylindrical electrostatic probe for direct measurement of electron density and electron temperature using two Langmuir probes at opposite ends of the spacecraft; and ion temperature probe for direct measurement of electron temperature, ion temperature, ionic composition, and charged particle density. Programmer had 216 possible commands, five of which could be stored. Spacecraft utilized 136 MHz real-time, 400 MHz recorded data/playback, and 136 MHz beacon transmission systems. Power: three nickel cadmium batteries of 17 cells each.

Project Results – ISIS B was launched March 31, 1971, from the Western Test Range in California. Orbit was 844 by 888 miles, with an inclination of 88.15 degrees. All experiments were operating and returning useful data.

Major Participants – Conducted jointly by the Communications Research Centre and NASA. Communications Research Centre, satellite design authority and Canadian management; NASA Goddard Space Flight Center, U.S. management; RCA Victor, Ltd., Montreal, prime spacecraft contractor; Communications Research Centre (4), National Research Council, University of Western Ontario, York University, and University of Calgary, Canadian experimenters; NASA Goddard Space Flight Center and University of Texas at Dallas, U.S. experimenters; McDonnell Douglas, launch vehicle prime contractor; Kennedy Space Center's Unmanned Launch Operations, launch operations.

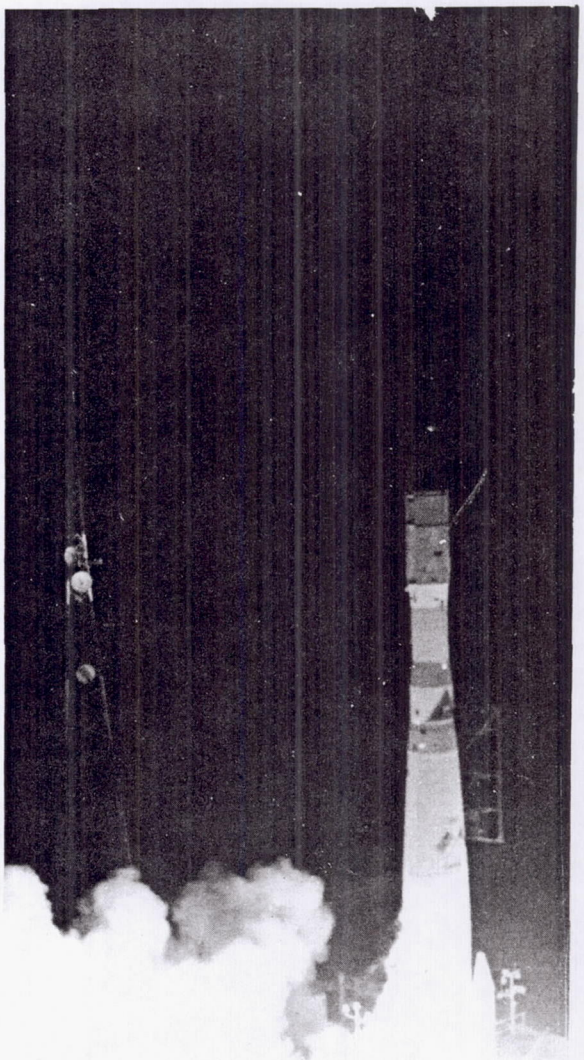


ISIS B, the third satellite in a joint Canadian-U.S. program to study the ionosphere from space, was launched successfully on March 31, 1971 from the Western Test Range, Lompoc, California.

Key Spacecraft Personnel		Affiliation
PE	C. A. Franklin	Communications Research Centre
CO	L. H. Brace	NASA-GSFC
PS	L. H. Brace	NASA-GSFC
CO	J. H. Whitteker	Communications Research Centre
SC	F. R. Schmerling	NASA Headquarters
MG	F. W. Gaetano	NASA Headquarters
PM	C. A. Franklin	Communications Research Centre
PM	L. H. Brace	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Sweep Frequency Sounder	OI	J. Turner	Ionospheric Prediction Service
	OI	M. Sylvain	LGE
	OI	O. Holt	Auroral Observatory
	PI	J. H. Whitteker	Communications Research Centre
	OI	Y. Ogata	Radio Research Laboratory
	OI	R. Raghavarao	Physical Research Laboratory
	OI	J. E. Jackson	NASA-GSFC
	OI	C. E. Petrie	Communications Research Centre
	OI	R. B. Norton	NOAA-ERL
	OI	K. I. Chan	NASA-ARC
	OI	R. S. Unwin	Department of Science and Industry Research

Experiment	Experiment Personnel		Affiliation
Fixed Frequency Sounder	PI	W. Calvert	Lockheed Palo Alto
	OI	R. B. Norton	NOAA-ERL
	OI	C. E. Petrie	Communications Research Centre
	OI	J. H. Whitteker	Communications Research Centre
	OI	J. M. Warnock	NOAA
VLF Experiment	PI	R. E. Barrington	Communications Research Centre
	OI	F. H. Palmer	Communications Research Centre
Energetic Particle Detector	PI	T. B. McDiarmid	National Research Council of Canada
	OI	J. R. Burrows	National Research Council of Canada
Electron + Proton Particle Detector 10eV-10keV	PI	W. J. Heikkila	University of Texas, Dallas
Ion-Mass Spectrometer	PI	J. H. Hoffman	University of Texas, Dallas
Cylinder Electrostatic Probe	PI	L. H. Brace	NASA-GSFC
	OI	J. A. Findlay	NASA-GSFC
Retarded Potential Analyzer	PI	E. J. Maier	NASA-GSFC
	OI	B. E. Troy, Jr.	U.S. Naval Research Laboratory
	OI	J. I. Donley	NASA-GSFC
Radio Beacon	PI	P. A. Forsyth	Western Ontario University
	OI	G. F. Lyon	Western Ontario University
	OI	E. H. Tull	Western Ontario University
Cosmic Radio Noise	PI	T. R. Hartz	Communications Research Centre
3914-5577 A Photometer	PI	C. D. Anger	University of Calgary
6300 A Photometer	PI	G. G. Shepherd	York University



ISIS B lifts off from the Western Test Range in Lompoc, California.

SAN MARCO C

Launch Vehicle – Scout B. Same as Explorer XLII.

Spacecraft Description – Spherical structure, 30 inches in diameter, with four 19-inch antennas protruding from the top of the sphere. An inner structure, containing the scientific instrumentation, was connected to the spacecraft's outer shell by triaxial flexing members. This construction caused a drag differential between the inner and outer segments of the spacecraft, which was used in carrying out the drag balance experiment. Solar cells mounted on the sphere provided power to two nickel-cadmium batteries which power the spacecraft and its experiments. San Marco C also carried a standby mercury oxide battery. The spacecraft was spin-stabilized at 6 rpm and weighed 360 pounds.

Project Objectives – To orbit data on atmospheric drag, density, neutral composition and temperature data in the upper atmosphere.

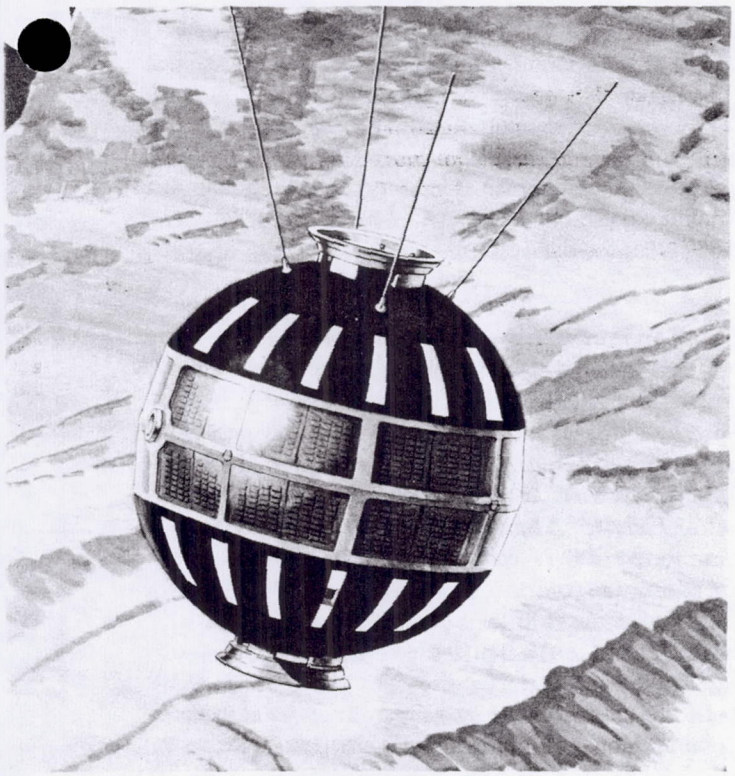
Spacecraft Payload – Three experiments: Drag balance measurement instrumentation; Omegatron, which measured the temperature and distribution of molecular nitrogen in the path of the spacecraft; and a mass spectrometer which measures neutral atmospheric composition, similar to spectrometers flown on Explorers XVII and XXXII.

Project Results – San Marco C was launched April 24, 1971, from the Italian-operated San Marco launch platform in the Indian Ocean three miles off the coast of Kenya, Africa. The spacecraft was placed into an approximate 130 by 500 mile near-equatorial orbit with a period of 93 minutes. It returned measurements until its decay on November 29, 1971.

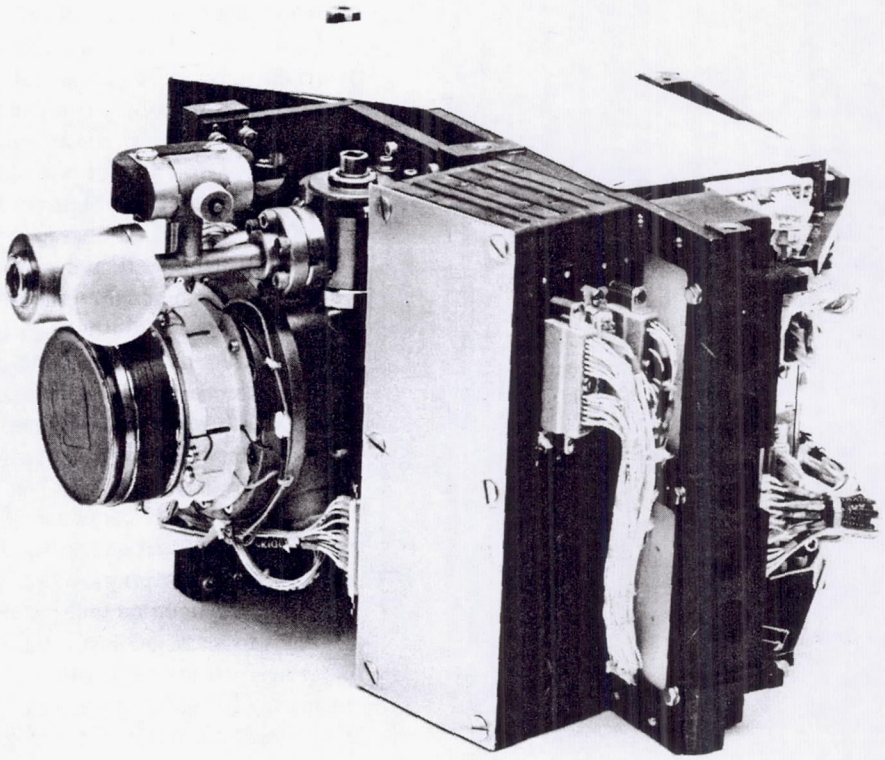
Major Participants – Centro Ricerche Aerospazial, the Italian space agency, spacecraft management; NASA Langley Research Center, launch vehicle management; Ling-Temco-Vought, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	A. J. Caporale	NASA-GSFC
PS	G. P. Newton	NASA-GSFC
CO	M. D. Handegard	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Drag Balance Experiment	PI	L. Broglio	National Research Council, Italy
Neutron Atmospheric Comp. Spectrometer	PI	G. P. Newton	NASA-GSFC
	OI	D. T. Pelz	NASA-GSFC
Atmosphere Nitrogen Density	PI	N. W. Spencer	NASA-GSFC
	OI	G. R. Carignan	University of Michigan



Artist's sketch of the San Marco C, an Italian-U.S. space venture to study atmosphere density, composition, and temperature behavior under varied solar and geomagnetic activities.



This experiment package was carried on board the San Marco C.

1971

MARINER I (9)
also MARINER H (8)

Launch Vehicle – Atlas-Centaur, SLV-3C plus Centaur stage. First stage propulsion included two 171,000-pound-thrust engines, one 60,000-pound-thrust sustainer engine and two 680-pound-thrust vernier engines. SLV-3C guidance was provided by pre-programmed pitch rates through booster engine cutoff, then switched to Centaur inertial guidance for sustainer phase. Centaur stage developed 30,000 pounds thrust from two 15,000-pound-thrust liquid hydrogen and liquid oxygen-fed engines. SLV-3C weighed 283,577 pounds; Centaur, 37,657. Total vehicle height: 113 feet.

Spacecraft Description – Basic structure was a 40-pound, eight-sided forged magnesium framework (54.5 inches diagonally, 18 inches deep) with eight electronic compartments. Four solar panels, each 84.5 inches long, 35.5 inches wide, were attached by outrigger structures to the top of the octagon. Each panel had a solar cell area of about 20.7 square feet, or a total cell surface of approximately 83 square feet. With solar panels deployed, the spacecraft had a "wingspan" of 22 feet, 7.5 inches. Height of the spacecraft from bottom of scan platform to top of the low-gain antenna and rocket nozzle was 7.5 feet. Two sets of attitude control jets, consisting of six jets each for three-axis stabilization, were mounted at the tips of the four solar panels. Two spherical propellant tanks for the liquid-fueled rocket engine were mounted side by side atop the octagonal structure. The two-position high-gain antenna was attached to the spacecraft by a super-structure atop the octagon. Its aluminum honeycomb dish reflector was circular, 40 inches in diameter, and parabolic in cross-section. The low-gain omnidirectional antenna was mounted at the top of a circular aluminum tube four inches in diameter and extending vertically 57 inches from the top of the octagonal structure. A horn-shaped medium-gain antenna was mounted on a solar panel outrigger. The Canopus star tracker assembly was located on the upper ring structure of the octagon for a clear field of view between two solar panels. The cruise sun sensor and sun gate were attached to a solar panel outrigger. Mariner I (9)'s propulsion system – for small trajectory corrections, deceleration into Mars orbit and trim maneuvers – was capable of at least five starts and produced a continuous thrust of 300 pounds. Hypergolic propellants were monomethyl hydrazine and nitrogen tetroxide. Timing, sequencing and computations for other subsystems aboard the spacecraft were performed by the vehicle's Central Computer and sequencer and gave the spacecraft the capability to operate through its basic mission without ground commands – with the exception of spacecraft maneuvers. Critical events were backed up by ground command capability. Two-way communications were provided by a radio link between Earth tracking stations and a dual transmitter-single receiver system aboard the spacecraft. The on-board communications system included a telemetry subsystem, command subsystem, data storage subsystem and high-, low- and medium-gain antennas. Primary spacecraft power source was an arrangement of 14,742 photovoltaic solar cells mounted on four panels which face the sun during most of the flight to Mars and during orbital operations. Nominal power capability of the panels was about 800 watts at maximum voltage for cruise conditions, decreasing to about 500 watts at Mars. Maximum power demand during orbital operations was about 400 watts. Science instruments were mounted on a scan platform which can be rotated about two axes to point the instru-

ment toward Mars during the spacecraft's approach to the planet and while in orbit. Thermal control on the top and bottom of Mariner's basic octagon was provided by multi-layered aluminized Teflon, while temperature control of six of the electronics compartments was provided by polished metal louvers actuated by coiled bimetallic strips. The strips acted as spiral-wound springs that expand and contract as they heat and cool. The science platform and its array of instruments at the bottom of the octagon was also covered by a thermal blanket. Launch weight, including 1,000 pounds of fuel and oxidizer, was about 2,200 pounds.

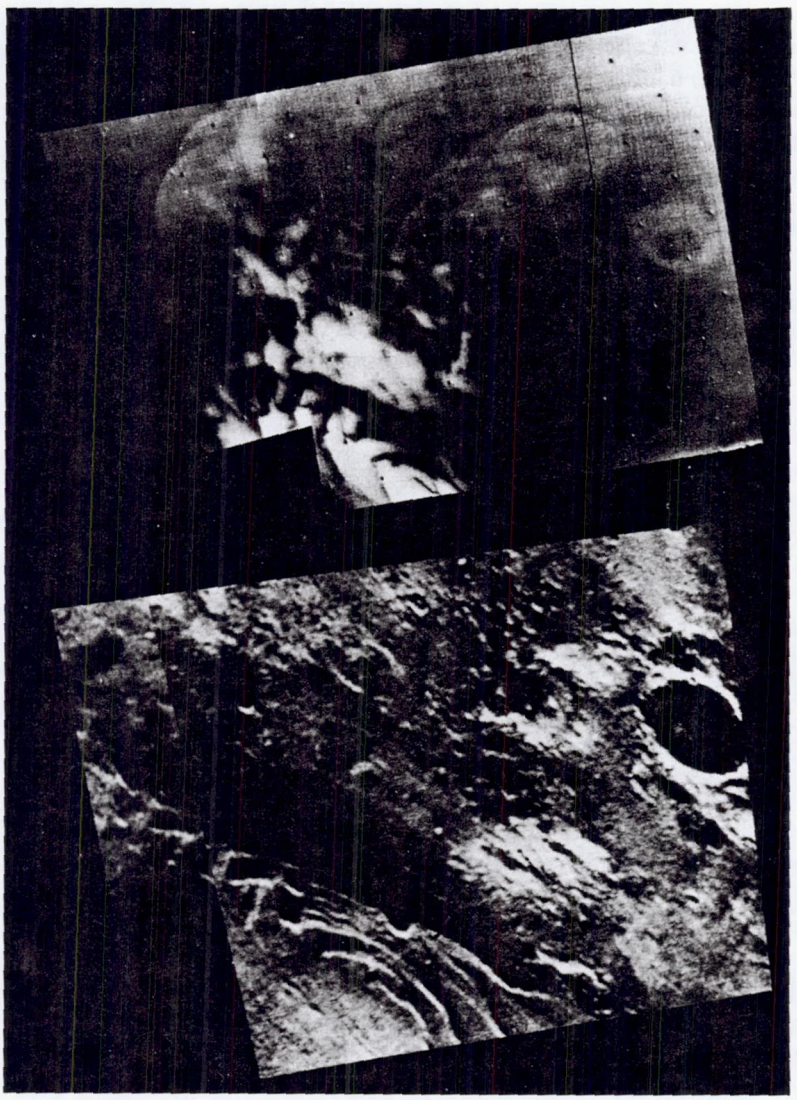
Spacecraft Payload – Composed of spacecraft subsystems responsible for gathering, formatting, and transmitting data to the Earth during periods of scientific observation. These included: TV subsystem, consisting of two cameras and an electronics package, with one camera configured to take wide-angle, low-resolution pictures and the other to take narrow-angle, high-resolution pictures; an Ebert-Fasti type ultraviolet spectrometer to measure incident ultraviolet radiation emitted by gases in the Martian upper atmosphere; an infrared radiometer to measure infrared heat radiation from the Martian surface; an infrared interferometer spectrometer to make a series of interferograms of the planet surface, deep space and warm blackbody sources; a data automation subsystem for sampling, digitizing, formatting and output processing of all data from the science experiments; a data storage subsystem to record the high-resolution 132.3 kilobits/sec video data stream from the data automation subsystem, store it until an opportune phase of the mission, and then play back through the flight telemetry subsystem which gathers data from many sources and outputs a single composite telemetry signal to the radio system for transmission to Earth.

Project Objectives – After a 167-day trip from Earth and insertion in orbit around Mars, Mariner I (9)'s basic 90-day mission was to: radio back to Earth between 25 and 30 billion bits of scientific information about Mars; take about 60 television pictures a day for a total of more than 5,000 pictures; take scores of TV pictures of the two moons; map more than 70 percent of the entire Martian surface; study the temperature and composition of the planet's surface with infrared instruments; study the composition and structure of the atmosphere with an ultraviolet instrument; and determine the structure and pressure of the atmosphere by measuring changes in Mariner's radio signal as it disappears and reappears behind the planet.

Project Results – Mariner I (9) was launched from Kennedy Space Center, Eastern Test Range, Fla., at 6:32 p.m., EST, May 30, 1971. The spacecraft was inserted into orbit around Mars on November 13, 1971, after a 167-day flight. Upon encounter, a massive dust storm obscured virtually the entire planet. The storm's gradual clearing allowed the spacecraft to begin its scientific mission, and by February 6, 1971, the dust had settled in all areas of the planet except the north polar regions. By that time, Mariner I (9) had mapped more than one-third of the planet's surface. Despite the delay, the spacecraft was expected to achieve virtually all its initial objectives. Project scientists were pleased with the volume of data that was returned from the space-

craft. Mariner I (9) combined the original mission objectives of Mariner H (8) which failed shortly after launch on May 8, 1971.

Major Participants – Program management: Office of Space Science and Applications, NASA Headquarters. Project management: NASA Jet Propulsion Laboratory. Launch vehicle project management: NASA Lewis Research Center. Launch operations: NASA Kennedy Space Center. Major spacecraft subsystem contractors: Litton Industries, data automation system; Santa Barbara Research Center, infrared radiometer; Electro-Optical Systems, television and power systems; University of Colorado, ultraviolet spectrometer; Martin Marietta, propulsion system; Motorola, command systems, central computer and sequencer, data storage electronics and radio; Texas Instruments, telemetry and infrared interferometer spectrometer; Honeywell Radiation Center, Canopus sensor. Launch vehicle prime contractor: General Dynamics.



(Top) This mosaic of Mariner 9 (H) photos during first orbit shows remnants of south polar cap of Mars dimly through great dust storm. (Bottom) Mariner 7 (F) photographed the same area in August 1969 when the entire area was covered with dry ice.

Key Spacecraft Personnel		Affiliation
PM	D. Schneiderman	NASA-JPL
PS	R. H. Steinbacher	NASA-JPL

Experiment	Experiment Personnel		Affiliation
Infrared Radiation	PI	G. Neugebauer	California Institute of Technology
	OI	H. H. Kieffer	US Geological Survey
	OI	G. Munch	California Institute of Technology
	OI	S. C. Chase, Jr.	Santa Barbara Research Center
	OI	E. D. Miner	NASA-JPL
Ultraviolet Spectrometer	PI	C. A. Barth	University of Colorado
	OI	J. B. Pearce	Science Applications Incorporated
	OI	C. W. Hord	University of Colorado
Infrared Interference Spectrometer	PI	R. A. Hanel	NASA-GSFC
	OI	B. J. Conrath	NASA-GSFC
	OI	C. Prabhakara	NASA-GSFC
	OI	G. V. Levin	Biospherics, Incorporated
	OI	B. Schlachman	NASA-GSFC
	OI	W. A. Hovis	NOAA-NESS
	OI	V. G. Kunde	NASA-GSFC
	OI	P. D. Lowman, Jr.	NASA-GSFC
	OI	J. Pirraglia	NASA-GSFC
	OI	T. E. Burke	NASA-JPL
	OI	J. C. Pearl	NASA-GSFC
Television Photography	PI	H. Masursky	US Geological Survey
	OI	G. DeVaucouleurs	University of Texas, Austin
	OI	J. Lederberg	Stanford University
	OI	W. Thompson	Bellcomm, Incorporated
Dual Frequency Occultation	PI	Unknown	Unknown
	PI	J. D. Lowell	NASA-JPL
Celestial Mechanics	PI	A. J. Kliore	NASA-JPL
S-band Occultation	OI	D. L. Cain	NASA-JPL
	OI	G. Fjeldbo	NASA-JPL
	OI	B. L. Seidel	NASA-JPL
Multidisc Analyzer PH	PI	Unknown	Unknown
Evaluator Haze Effects	PI	G. A. Briggs	NASA-JPL
Martian Mapping	PI	G. DeVaucouleurs	University of Texas, Austin
Video Analysis	PI	J. Lederberg	Stanford University
Radiation Detector	PI	J. A. VanAllen	University of Iowa

SOLRAD-X (Explorer XLIV)

Launch Vehicle – Scout B. Same as Explorer XLII.

Spacecraft Description – A 12-sided structure 30 inches in diameter and approximately 23 inches in height, with four symmetrically placed 7-by 21-inch solar cell panels hinged at the center station. Solar cell panels were folded along the length of the structure and were deployed after third stage burnout, serving as the four elements of a "turnstile" antenna system. The electronic subsystems included two nonredundant telemetry transmitters operating on separate frequencies of 137.710 MHz and 136.380 MHz, three spin replenishment and four spin-axis attitude control subsystems, and a command subsystem. Three spin replenishment and four spin-axis attitude control subsystems were designed to maintain the spin rate at 60 rpm and the spin-axis within ±2° of the Sun line. Solar sensors determined the angle to the Sun and automatically applied control signals to the attitude spin subsystem. Spacecraft weight: 260 pounds.

Project Objectives – Third in a series of solar radiation spacecraft (SOLRAD) to continuously monitor solar electromagnetic radiation (X-ray and ultraviolet) and to measure, on command, stellar radiation from other celestial sources. Information collected was expected to contribute to a better understanding of the physical processes involved in solar flares and other solar activity, and the potential effects of this activity on short-wave communications, as well as on future manned space travel.

Spacecraft Payload – Fourteen experiments included the following sensors: 18 ionization chambers for solar X-ray monitor, solar electron temperature, solar Lyman Alpha bursts and monitor, solar ultraviolet monitor, solar UV continuum flash, background X-ray level, and solar hard X-ray continuum; a Cesium Iodide (Sodium) scintillating crystal and photomultiplier to monitor solar hard X-ray; Lithium Flourine photometer for solar excitation of F-layer; Thermistor for skin antisolar temperature; and large-area proportional counter for X-ray variations.

Project Results – SOLRAD X was launched July 8, 1971, from Wallops Island, Va., into a 269- by 393-mile orbit. Data was received continuously, and was shared with the international scientific community through COSPAR. Expected lifetime was 3 years.

Major Participants – Navy Research Laboratory and NASA Office of Space Science and Applications, program management; Naval Research Laboratory, technical and scientific program management; NASA Goddard Space Flight Center, tracking and data systems management; NASA Langley Research Center, launch vehicle management; NASA Wallops Station, launch operations; LTV Aerospace Corp., launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	E. W. Peterkin	US Naval Research Laboratory
PS	R. W. Kreplin	US Naval Research Laboratory
MG	J. R. Holtz	NASA Headquarters
SC	J. D. Bohlin	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Solar X-ray Ultraviolet Detectors	PI	R. W. Kreplin	US Naval Research Laboratory
	OI	D. D. Brousseau	US Naval Research Laboratory
	OI	E. T. Byram	US Naval Research Laboratory
	OI	J. H. Carver	University of Adelaide
	OI	R. F. Fisenhauer	US Naval Research Laboratory
	OI	G. G. Fritz	US Naval Research Laboratory
	OI	D. M. Horan	US Naval Research Laboratory
	OI	A. T. McClinton	Phoenix Corporation
	OI	R. G. Taylor	US Naval Research Laboratory
	OI	J. G. Winkler	US Naval Research Laboratory
Stellar X-ray Telescope	PI	R. W. Kreplin	US Naval Research Laboratory

APOLLO XV, P&F Subsatellite

Launch Vehicle – Saturn V (SA-510). Similar to the Apollo XIV vehicle with an increased capability to deliver a payload more than 4,000 pounds heavier than Apollo XIV. Major operational changes were an Earth parking orbit altitude of 90 nm (rather than 100) and a launch azimuth range of 80 to 100 degrees (rather than 72 to 96). Launch vehicle weight (excluding spacecraft) at liftoff: 6,295,500 pounds. Spacecraft weight: 116,293 pounds. Total vehicle weight at launch: 6,411,793 pounds.

Spacecraft Description – Apollo 15: In addition to the modifications to the Apollo Command and Service Modules (Endeavor) as a result of the Apollo XIII accident, further changes for the Apollo XV mission were made to provide for longer emission duration and remote sensing capabilities from lunar orbit required in the scientific "J" missions, beginning with Apollo XV. Scientific Instrument Module (SIM) package and one more hydrogen tank were added, and an oxygen tank isolation valve was relocated – all in the service module. New control panels for an extra-vehicular (EVA) station and a control panel for the SIM package were added in the Command Module. The SIM package, designed for payloads up to 1,700 pounds and located in a formerly empty sector (Bay I) of the SM, was covered by a 170-pound panel. Significant differences between LM-8 (Apollo XIV) and LM-10 (Apollo XV "Falcon") were: a fifth battery added to descent stage for total 2,075 amp hours (batteries upgraded from 400 AH each to 415); second descent stage water tank added for a total 337 pounds capacity; second descent stage gaseous oxygen (GOX) tank added for total 85 pound capacity, permitting six 1,410 psi Portable Life Support System (PLSS) recharges; addition of a system capable of storing 1,200 cc per-man-per-day urine and 100 cc per-man-per-day PLSS condensate; additional thermal insulation for longer stay time (67 hours vs. 35 hours on LM-8); and additional descent stage payload. Changes in descent engine included quartz-lined engine chamber instead of silica-lined, a 10-inch nozzle extension, and a 3.36-inch extension to propellant tanks to increase total capacity of 1,150 pounds, yielding 157 seconds hover time. Total LM weight at launch: 36,230 pounds.

P&F Subsatellite: Hexagonal: 31 inches high and 14 inches diameter, spin-stabilized at 12 rpm. Weight: 80 pounds.

Project Objectives – Apollo XV: First of the Apollo "J" mission capable of longer stay time on the moon and greater surface mobility, Apollo XV had four primary objectives, falling in the general categories of lunar surface science, lunar orbital science, and engineering – operational. Mission objectives were exploration of the Hadley-Appenine region, set up and activate lunar surface scientific experiments, make engineering evaluations of new Apollo equipment, and conduct lunar orbital experiments and photographic tasks. Exploration and geological investigations at the Hadley-Appenine landing site were enhanced by the addition of the Lunar Roving Vehicle. Setup of the Apollo lunar surface experiment package (ALSEP) was the third in a trio of operating ALSEPs (Apollo XII, XIV, and XV). Orbital science experiments were concentrated in any array of instruments and cameras in the SIM bay. Engineering and operational objectives included evaluation of modifications to the LM made for carrying a heavier payload and for a lunar

stay time of almost three days. Changes to the Apollo spacesuit and to the PLSS were to be evaluated, and performance of the Lunar Roving Vehicle and the other new J-mission equipment that goes with it—lunar communications relay unit (LCRU) and the ground-controlled television assembly (GCTA). Another major mission objective involved the launching of a subsatellite into lunar orbit by the CSM shortly before beginning the return to Earth portion of the mission.

P&F Subsatellite: To investigate the moon's mass and gravitational variations, particle composition of space near the moon, and the interaction of the moon's magnetic field with that of Earth.

Spacecraft Payload – Substantially different in the amount of scientific instrumentation/exploration equipment aboard. The third ALSEP array included a passive seismic experiment for continuous measurement of moonquakes and meteorite impacts; lunar surface magnetometer for measuring the magnetic field at the lunar surface; solar wind spectrometer for measuring the energy and flux of solar protons and electrons reaching the moon; superthermal ion detector for measuring density of solar wind high and low-energy ions; cold cathode ion gauge for measuring variations in the thin lunar atmosphere; and the heat flow experiment to measure heat emanating from beneath the lunar surface. A percussive drill for drilling holes in the moon's crust for placement of the heat flow experiment sensors and for obtaining samples of the lunar crust was used for the first time. Two experiments independent of ALSEP were a solar wind composition experiment for determining the isotopic makeup of noble gases in the solar wind and the laser ranging retro-reflector experiment which acts as a passive target for Earth-based lasers in measuring Earth-moon distances over a long-term period. Experiments in the SIM bay of the Service Module were: gamma-ray spectrometer and X-ray fluorescence to measure lunar surface chemical composition along the orbital ground track, alpha-particle spectrometer to measure alpha particles from radioactive decay of random gas isotopes emitted from the lunar surface, mass spectrometer to measure the composition and distribution of the lunar atmosphere, and the Particles and Fields subsatellite. The SIM bay also contained equipment for orbital photography, including a 24-inch panoramic camera, three-inch mapping camera and a laser altimeter for accurately measuring spacecraft altitude for correlation with the mapping photos. The Lunar Roving Vehicle (LRV) was a four-wheel, electrically-powered, lightweight vehicle for transporting two astronauts on three exploration traverses of the Hadley-Appenine area. In addition to the crew, it carried tools, scientific equipment, communications gear and lunar samples. Folded into a small package to fit within the tight, pie-shaped confines of Quad I of the LM descent stage (occupied on previous missions by erectable S-band antenna and laser reflector), the LRV was required to unfold and deploy itself to the lunar surface with a minimum of assistance from the astronauts. The vehicle was 10.17 feet long, had a six-foot tread width, was 44.8 inches high, and had a 7.5-foot wheelbase. Each wheel was individually powered by a quarter-horsepower motor and its top speed on a relatively smooth surface was about eight miles per hour. Weighing about 460 pounds (Earth weight), when deployed on the moon the LRV could carry a total payload of about 1,080 pounds—more than

twice its own weight. It had an endurance period of 78 hours during the lunar day, capable of several exploration sorties up to a cumulative distance of 40 miles. It was designed to negotiate step-like obstacles 9.8 inches high and to cross crevasses 22.4 inches wide. Fully loaded, it could climb and descend slopes as steep as 25 degrees, stop and hold on slopes of up to 30 degrees. Cameras aboard the Apollo XV Command Module consisted of one 70mm Hasselblad electric camera, a 16mm Maurer motion picture camera, a 35mm Nikon F single-lens reflex camera. Aboard the Lunar Module were two 70mm Hasselblad data cameras fitted with 60mm Zeiss metric lenses, an electric Hasselblad with 500mm lens and two 16mm Maurer motion picture cameras with 10mm lenses. One Hasselblad and one motion picture camera were stowed in the modular equipment stowage assembly (MESA) in the LM descent stage. The EV-A-7LB space suit differed from earlier suits by having a waist joint that allowed greater mobility while the suit was pressurized – stooping down for setting up lunar surface experiments, gathering samples, and for sitting on the Lunar Roving Vehicle. Crew for Apollo XV included Commander David R. Scott, 39, an Air Force colonel; Command Module Pilot Alfred M. Worden, 39, an Air Force major; and Lunar Module Pilot James B. Irwin, 41, an Air Force lieutenant colonel.

P&F Subsatellite: One watt S-band transponder, magnetic core memory unit with 49,152 bit capacity, with a transmit rate of 128 bits per second, and 25 watts of solar power.

Project Results – Apollo XV; Launched from Complex 39A at Cape Kennedy, Fla., at 9:34 a.m., EDT, July 26, 1971 – only 187 milliseconds off schedule. The TLI and Hybrid Transfer maneuvers were combined into a single "optimized TLI" S-IVB engine burn. A minor problem early in the mission involving a short circuit in a SPS engine firing switch was successfully cleared through revised procedures for the LOI and subsequent SPS maneuvers. Scott and Irwin flew their LM to a perfect landing at 6:16 P.M. EDT, July 30, at Hadley Rille about 1,500 feet north and east of the targeted landing point near a crater named Salyut. Landing approach over the Appenine Range – one of the highest on the moon – was at an angle of 26 degrees, the steepest approach yet used in Apollo missions. During three periods of EVA on July 31, August 1, and August 2, Scott and Irwin completed a record 18 hours, 37 minutes of exploration; traveled 17.5 miles in the first car that man has ever driven on the moon; collected more than 170 pounds of lunar samples; set up the ALSEP array; obtained a core sample from about 10 feet beneath the lunar surface; and provided extensive oral descriptions and photographic documentation of geologic features in the vicinity of the landing site during the three days (66 hours, 55 minutes) on the lunar surface. On August 2, Falcon fired its ascent stage engine and lifted off the moon for its rendezvous with CM Endeavor. For the first time, the lunar liftoff was seen on Earth via the LRV television camera. The two spacecraft docked as Endeavor began its 50th lunar orbit. On the 74th revolution, the Particles and Fields subsatellite was spring-launched from the SM SIM Bay, and on the next revolution, August 4, a 2-minute, 21-second SPS burn put Apollo XV on its path back to Earth. On



Apollo XV crew left this plaque on the Moon which carries the names of all fourteen American and Soviet space explorers who had died during the the two nation's space programs. Just in front of plaque is a small figure representing fallen astronaut.

August 5, Worden became the first man to carry out a deep space EVA. He exited the CM, climbed toward the rear of the SM and retrieved film casettes from the SIM bay cameras and returned to the CM. The entire operation was completed in 18 minutes (one hour had been scheduled in the flight plan). At approximately 4:46 p.m. EDT, August 7, Apollo XV splashed down in the Pacific Ocean, about 335 miles north of Honolulu, ending a flight of 12 days, 7 hours. The crew was picked up by helicopters from the prime recovery ship, USS Okinawa, 6.32 miles from the targeted touchdown point. During the final stages of descent on its three main parachutes, the CM crew and shipboard observers noted one of the parachutes became only partially inflated following jettison of RSC fuel remaining on board. As a result of the loss of one parachute, the CM impacted at 21.8 m.p.h., instead of the planned 19 m.p.h. Apollo XV set several new records for manned spaceflight: heaviest payload in a lunar orbit of approximately 107,000 pounds; maximum radial distance traveled on the lunar surface away from the spacecraft of about 17.5 miles (previous high was 2.1 miles on Apollo XIV); most lunar surface EVAs (three) and longest total of duration for lunar surface EVAs (18 hours, 37 minutes – almost the total time spent in lunar orbit by Apollo VIII); longest time in lunar orbit (about 145 hours; only two hours less than the entire Apollo VIII mission); longest manned lunar mission (295 hours); longest Apollo mission (295 hours – previous high was 244 hours, 36 minutes on Apollo XII); first satellite placed in lunar orbit by a manned spacecraft, and first deep space and operational EVA.

P&F Subsatellite: Ejected from SIM Bay at 12:13 p.m. EDT, August 4. Initial orbit of 55 by 75 nm decayed to 38 by 95 nm after 6 months, primarily from effect of "mascons." Data obtained from the mission has shown that a magnetic field circles the moon, that its fluctuations reflect surface irregularities, that the side away from the Earth has a much more uneven field, and that the mascons may affect the magnetic field.

Major Participants – NASA Office of Manned Space Flight, program management; NASA Manned Spacecraft Center, spacecraft management; North American Rockwell, CM and SM spacecraft prime contractor; SPS, Aerojet-General, principal and subcontractors; AVCO, ablative heat shield; Collins, communication and data subsystems; Garrett, environmental control system; Grumman, LM spacecraft prime contractor; General Motors (manufacturing) and MIT (technical management), primary guidance and navigation system; North American Rockwell, ascent engine; RCA, communications subsystems and radar and control electronics; TRW, descent engines and abort guidance system; Hamilton-Standard, astronauts' portable life support systems; ILC Industries, space suits; Bendix, Apollo Lunar Surface Experiments Package; Boeing, Lunar Rover Vehicle prime contractor; Delco Electronics Division of General Motors major subcontractor, IBM, IU prime contractor; Boeing, Apollo-Saturn V technical integration and evaluation; GE, Apollo checkout equipment, related engineering design, quality management, and engineering support; TRW, mission trajectory control and spacecraft systems analysis; NASA Marshall Space Flight Center, launch vehicle management; Boeing, first stage prime contractor; North American Rockwell, second stage; McDonnell Douglas, third stage; NASA Kennedy Space Center, launch Network; NASA Goddard Space Flight Center, Manned Space Flight Center management.

Key Spacecraft Personnel		Affiliation
Apollo XV		
PM	R. Petrone	NASA Headquarters
PS	Unknown	Unknown
SC	Unknown	Unknown
MG	F. I. Roberson	NASA Headquarters
SC	J. B. Hanley	NASA Headquarters
PM	W. F. Eichelman	NASA-JSC

Experiment	Experiment Personnel		Affiliation
Apollo XV			
Handheld Photography	PI	F. J. Doyle	US Geological Survey
	CO	A. Patteson	NASA-JSC
	CO	R. J. Allenby, Jr.	NASA Headquarters
Panoramic Photography	PI	F. J. Doyle	US Geological Survey
Metric Photography	PI	F. J. Doyle	US Geological Survey
Stellar Photography	PI	F. J. Doyle	US Geological Survey
	CO	S. N. Hardee, Jr.	NASA-JSC
	CO	Unknown	NASA-JSC
Laser Altimeter	PI	W. M. Kaula	University of California, Los Angeles
Ultraviolet Photography	PI	T. C. Owen	Illinois Institute of Technology

Experiment	Experiment Personnel		Affiliation
	CO	S. N. Hardee, Jr.	NASA-JSC
Gegenschein Photos	PI	L. Dunkelman	NASA-GSFC
	CO	S. N. Hardee, Jr.	NASA-JSC
Gamma-Ray Spectrometer	PI	J. R. Arnold	University of California, San Diego
	OI	A. E. Metzger	NASA-JPL
	OI	L. E. Peterson	University of California, San Diego
	OI	J. I. Trombka	NASA-GSFC
	CO	L. E. James	NASA-JSC
X-Ray Fluorescence	PI	I. Adler	NASA-GSFC
	OI	A. E. Metzger	NASA-JPL
	OI	P. Gorenstein	Harvard College Observatory
	OI	H. Gursky	Harvard College Observatory
	OI	J. I. Trombka	NASA-GSFC
	CO	L. E. James	NASA-JSC
Alpha Particle Spectrometer, S162	PI	P. Gorenstein	Harvard College Observatory
	OI	I. Adler	NASA-GSFC
	OI	J. R. Arnold	University of California, San Diego
	OI	H. Gursky	Harvard College Observatory
	OI	A. E. Metzger	NASA-JPL
	OI	J. I. Trombka	NASA-GSFC
S-Band Transponder	PI	W. L. Sjogren	NASA-JPL
	OI	B. Gottlieb	Southwest Center for Advanced Studies
	OI	J. Lorell	NASA-JPL
	OI	P. M. Muller	NASA-JPL
	CO	P. E. Lafferty	NASA-JSC
Window Meteoroid (S176)	PI	B. G. Cour-Palais	NASA-JSC
	CO	S. N. Hardee, Jr.	NASA-JSC
	OI	M. L. Brown	Lockheed Electronics
	OI	D. S. McKay	NASA-JSC
Mass Spectrometer Experiment	PI	J. H. Hoffman	University of Texas, Dallas
	OI	V. M. Dauphin	NASA-JSC
Bistatic Radar Experiment	PI	H. T. Howard	Stanford University
	OI	V. R. Eshleman	Stanford University
	OI	A. M. Peterson	Stanford University
	OI	G. L. Tyler	Stanford University
	CO	P. E. Lafferty	NASA-JSC
Passive Seismic Experiment	PI	G. V. Latham	University of Texas, Galveston
	OI	W. M. Ewing	

Experiment	Experiment Personnel		Affiliation
	OI	F. Press	Massachusetts Institute of Technology
	OI	G. H. Sutton	University of Hawaii
Soil Mechanics	PI	J. K. Mitchell	University of California, Berkeley
	OI	D. Carrier	NASA-JSC
	OI	N. Costes	NASA-JSC
	OI	L. G. Bromwell	Massachusetts Institute of Technology
Lunar Surface Magnetometer	PI	P. Dyal	NASA-ARC
Solar Wind Spectrometer	PI	C. W. Snyder	NASA-JPL
Suprathermal Ion	PI	J. W. Freeman	Rice University
	OI	F. C. Michel	Rice University
	OI	H. K. Hills	NASA-GSFC
Heat Flow	PI	M. G. Langseth	Lamont-Doherty Geophysical Observatory
	OI	S. P. Clark, Jr.	Yale University
Cold Cathode Ion	PI	F. S. Johnson	University of Texas, Dallas
	OI	D. E. Evans	Unknown
Laser Retro-Reflector	PI	J. Faller	University of Colorado
Lunar Dust Detector, M515	PI	J. R. Bates	NASA-JSC
Field Geology	PI	G. Swann	U.S. Geological Survey
	OI	W. R. Muehlberger	U.S. Geological Survey
Solar Wind Composition	PI	J. Geiss	University of Berne
S-Band Transponder (S-164)	PI	W. L. Sjogren	NASA-JPL
Particle Shadow Layer, S173	PI	K. A. Anderson	University of California, Berkeley
	OI	L. M. Chase	University of California, Berkeley
	OI	R. P. Lin	University of California, Berkeley
	OI	J. McCoy	NASA-JSC
	OI	G. Schubert	University of California, Los Angeles
	CO	P. E. Lafferty	NASA-JSC
Magnetometer, S174	PI	P. J. Coleman, Jr.	University of California, Los Angeles
S-Band Transponder	PI	W. L. Sjogren	NASA-JPL

CAS-A/EOLE-I

Launch Vehicle – Scout B, same as Explorer XLII.

Spacecraft Description – Octagonal cylinder, 28 inches in diameter and 23 inches in height. Eight solar panels deployed in windmill fashion from top of spacecraft. Extending from top of spacecraft was 33-foot boom for gravity gradient stabilization. At bottom of spacecraft was a four-arm conical spiral antenna. Solar cells, supplemented by rechargeable silver-cadmium batteries, provided 20 watts of power to the spacecraft and its experiments. Weight: 186 pounds.

Project Objectives – To collect information on winds, temperatures and pressures from instrumented balloons flying at about 39,000 feet in the Southern hemisphere, and to investigate wind circulation in the atmosphere. A secondary objective was to demonstrate satellite-and-balloon technology for making range and range-rate measurements to determine balloon positions.

Spacecraft Payload – Communications and data handling package for balloon interrogation and transmission of balloon data to Earth. Two transmitters with PCM/PM emission were used. Balloon interrogation transmitter operated at 464 MHz with a power of 4 watts. The second transmitter operated in the 136-138 MHz range with a power of 250 mw to transmit to ground stations.

Project Results – EOLE was launched August 16, 1971, from Wallops Station, Virginia, achieving a 560-mile circular orbit, with an inclination of 50 degrees. Initial period was 103 minutes. Approximately 50 instrumented balloons were launched from Argentina during the following five months to carry out atmospheric weather experiments.

Major Participants – Centre National d'Etudes Spatiales (CNES), program management and spacecraft; NASA Langley Research Center, launch vehicle management; Ling-Temco-Vought, launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
PM	S. R. Stevens	NASA-GSFC
PS	W. R. Bandeen	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Upper Atmosphere Weather Relay Systems	PI	W. R. Bandeen	NASA-GSFC
	OI	A. Kasahara	National Center for Atmospheric Research
	OI	J. Angell	NOAA
	OI	Y. Mintz	University of California, Los Angeles
	OI	P. Morel	CNRS

OSO-H (7), TETR-4

Launch Vehicle – Long Tank Thrust-Augmented Delta (LTTAD). Modified Thor first stage with liquid fueled main engines yielding 170,000 pounds of thrust, augmented by three strap-on solid propellant rockets to bring total first stage thrust to 326,000 pounds. Restartable liquid second stage had average thrust of 7,700 pounds. Height, including spacecraft and fairing, was 106 feet.

Spacecraft Description – OSO-H (7): Similar in appearance to earlier spacecraft. Weighing 1,400 pounds, it was more than twice as heavy as any previous OSO, due to increased payload and supporting systems, balance weights replacing momentum arms, and addition of an improved gyroscope for pointing accuracy. Spacecraft had two sections: a sail-like structure which carried the solar array and two sun-pointing experiments, and a nine-sided wheel which carried four experiments and spacecraft support instrumentation. Rotation of the wheel section at about 30 rpm stabilized the spacecraft in reference to the sun, allowing the four experiments to scan areas of interest every two seconds. The sail section locked onto the sun to orient the two sun-pointing experiments. A gyroscope in the sail acted as a sun-position memory unit for the sail-mounted experiments to reacquire the sun quickly after the spacecraft emerged from the Earth's shadow. Special scanning modes allowed the sun-pointing experiments to concentrate on areas of 60 by 60 arc minutes and 5 by 5 arc minutes. An orientation control system using gas jets and a magnetic torquing coil kept the spin axis perpendicular to the sun. A star scanner on the wheel section allowed spacecraft attitude determination to within 0.1 degree. A solar array on the sun-pointing side of the sail provided power to the spacecraft and experiments, while batteries provided power when in the Earth's shadow.

TETR-4: Similar to earlier TETR's. Octahedron, 12 inches on a side. Solar cells covered each of the eight sides to provide four to five watts of power. Top apex supported an S-band antenna with mast, and coiled VHF transmitter antennas deployed from two opposing apexes in the center plan. Launch and ejection fitting was mounted at bottom apex. The VHF command telemetry antenna section was near the bottom apex. S-band communications system radiated a signal of 0.8 watt. Magnetically stabilized, the spacecraft weighed 45 pounds.

Project Objectives – To continue the study of the sun's X-rays, gamma rays, cosmic rays, and radio emissions to better understand the sun's structure; to obtain clearer information on the sun's influence on the Earth; and to obtain baselines for studying other, more distant suns. Primary target for OSO-H was the solar corona. Pictures of the white light corona, the outermost atmosphere of the sun which is usually seen only during total solar eclipse, are obtained. A circular occulting disc on an extended boom produced an artificial eclipse for the imaging camera. Other experiments investigated solar flares in a continuing study of their influence on weather and communications on Earth, as well as to refining solar flare prediction techniques for use during manned space missions. Eventual goal, combining OSO data with those from other spacecraft programs, was to permit more qualified study of distant suns.

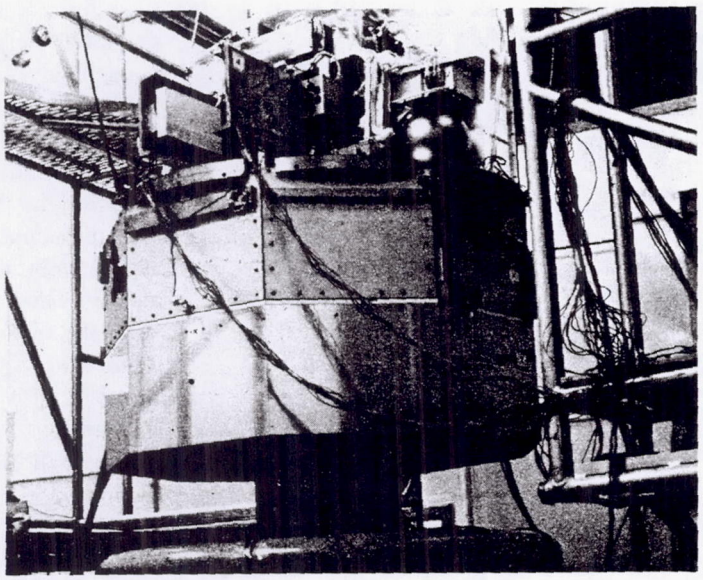
TETR-4: Orbiting transponder used to exercise NASA's Manned Space Flight Network.

Spacecraft Payload – OSO-H: Six experiments for solar observation, with the primary objective to study the solar corona. Two pointing experiments are X-ray and extreme ultraviolet spectroheliographs, and white light and extreme ultraviolet coronagraphs. The four spinning experiments to investigate: low energy cosmic X-rays, solar gamma rays, high energy cosmic X-rays, and hard solar X-rays.

TETR-4: Four to five-watt S-band transponder.

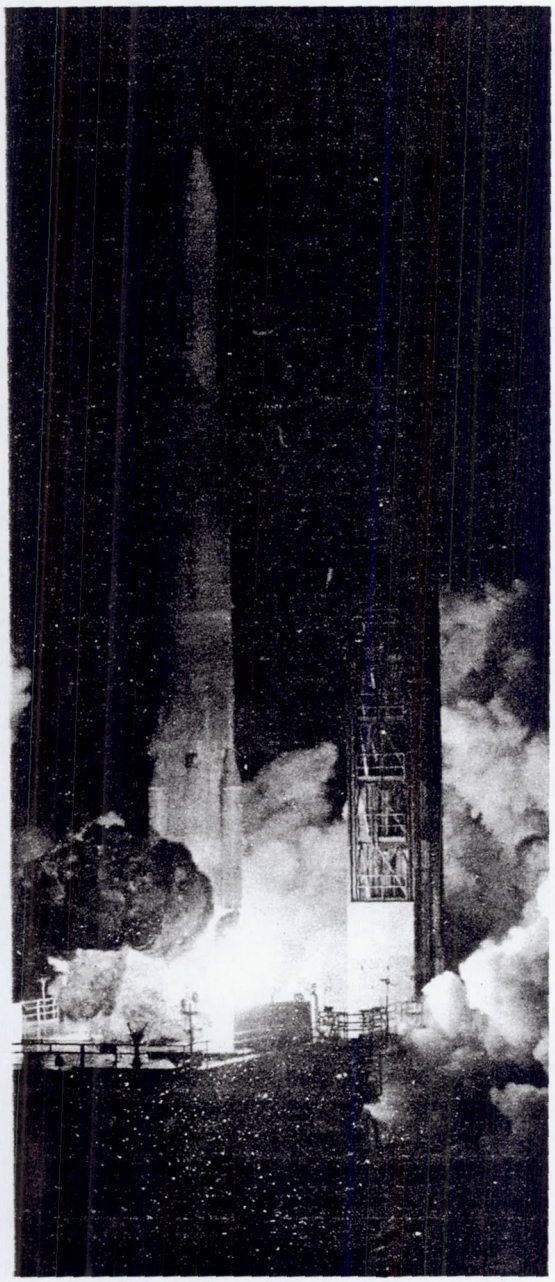
Project Results – OSO-H and TETR-4 were launched from Cape Kennedy on September 29, 1971. A hydraulic failure occurred in the second stage, and when OSO separated, it was tumbling. An elliptical, rather than the intended circular, orbit was achieved. Ground controllers were able to stabilize the spacecraft, orient it to the sun with 1 arc second pointing stability, and turn on all experiments, which were returning good data. TETR-4 also separated in a tumbling mode, and went into a near-circular orbit similar to that intended. The passive magnetic stabilization system damped out the tumble, stabilizing the spacecraft. Ground controllers were receiving good telemetry data. The normal mode of sending commands to TETR-4 had not been successful.

Major Participants - Spacecraft, launch vehicle and experiment management: NASA-Goddard. OSO spacecraft prime contractor: Ball Bros. Experiments: NASA-Goddard, Naval Research Laboratory, MIT, University of New Hampshire, University of California. TETR spacecraft management: NASA-Goddard. TETR spacecraft prime contractor: TRW. Launch vehicle prime contractor: McDonnell Douglas.



Shaker test of the OSO-H (7). This satellite carried experiments which helped continue the study of radio emission, X-rays, gamma rays, and cosmic rays.

The largest and most advanced spacecraft in the Orbiting Solar Observatory series (OSO) was launched aboard a Delta launch vehicle on September 29, 1971 from Cape Kennedy.



Key Spacecraft Personnel		Affiliation
OSO-H (7)		
PM	J. Thole	NASA-GSFC
PS	S.P. Maran	NASA-GSFC
MG	M.E. McDonald	NASA Headquarters
SC	G.K. Oertel	NASA Headquarters
TETR-4		
PM	C. H. Underwood	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
OSO-H (7)			
Spectroheliograph, 2-400A	PI	W. M. Neupert	NASA-GSFC
	OI	J. H. Underwood	Aerospace Corporation
	OI	R. D. Chapman	NASA-GSFC
	OI	R. J. Thomas	NASA-GSFC
	CO	W. A. White	NASA-GSFC
White + EUV Coronagraphs	PI	R. Tousey	U.S. Naval Research Laboratory
	OI	M. J. Koomen	U.S. Naval Research Laboratory
	OI	D. J. Michels	U.S. Naval Research Laboratory
X-Ray Sky Survey, 10-550 keV	PI	L. E. Peterson	University of California, San Diego
X-Ray Sources, 1.5-9A	PI	G. W. Clark	Massachusetts Institute of Technology
	OI	H. V. D. Bradt	Massachusetts Institute of Technology
	OI	W. H. G. Lewin	Massachusetts Institute of Technology
	OI	H. W. Schnopper	Massachusetts Institute of Technology
Solar X-Rays, 2-323 keV	PI	L. E. Peterson	University of California, San Diego
Gamma-Ray Spectrograph, 0.3-10 MeV	PI	E. L. Chupp	University of New Hampshire
	OI	H. P. Gilman	University of New Hampshire
	OI	A. A. Sarkady	University of New Hampshire

ITOS-B/NOAA-2

Launch Vehicle – Same as ITOS-A/NOAA-1

Spacecraft Description – Same as ITOS-A/NOAA-1

Project Objectives – Further augmentation of the Improved TIROS operational satellite system managed and operated by the National Environmental Satellite Service of National Oceanic and Atmospheric Administration to provide routine service of weather observations worldwide each day.

Spacecraft Payload – Same as ITOS-A/NOAA-1

Project Results – ITOS-B/NOAA-2 was launched October 21, 1971, from NASA Western Test Range, Vandenberg AFB, Calif., but failed to achieve usable orbit. Preliminary indication was that a nitrogen jet system in the second stage of the launch vehicle did not maintain attitude stability during the coast phase of the launch.

Major Participants – Conducted jointly by the Communications Research Centre and NASA. Communications Research Centre, satellite design authority and Canadian management; NASA Goddard Space Flight Center, U.S. management; RCA Victor, Ltd., Montreal, prime spacecraft contractor; Communications Research Centre, National Research Council, University of Western Ontario, York University, and University of Calgary, Canadian experimenters; NASA Goddard Space Flight Center and University of Texas at Dallas, U.S. experimenters; McDonnell Douglas, launch vehicle prime contractor; Kennedy Space Center's Unmanned Launch Operations, launch operations.

SSS-A EXPLORER 45

Launch Vehicle – Scout B. Same as Explorer 42.

Spacecraft Description – Eight-sided structure, 27 inches in diameter. Five booms: one 30 inches, two 24 inches and two 108 inches. Four 24-inch antennas were mounted around the top of the main body. Power was by solar arrays. Weight: 114 pounds.

Project Objectives – To measure aerodynamic heating and radiation damage during launch sequence, to flight test attitude data recorder, and to investigate particles and magnetic and electric fields in the magnetosphere.

Spacecraft Payload – The spacecraft carried three technology experiments: one to measure aerodynamic heating after fairing jettison, another to measure radiation damage, and a third to test a new lightweight attitude-data recorder. There were also three experiments to examine energetic particles and another three experiments to study the magnetic and electric field of the Earth's magnetosphere.

Project Results – Explorer 45 (Small Scientific Satellite) was launched November 15, 1971, from the Italian San Marco platform off the coast of Kenya. The spacecraft achieved orbit of 139 by 17,943 miles with an inclination of 3.5 degrees and a period of 517 minutes. This was the second American satellite to be launched by an Italian crew.

Major Participants – Spacecraft, launch vehicle and experiment management: NASA Langley. Launch vehicle prime contractor: Ling-Temco-Vought.

Key Spacecraft Personnel		Affiliation
PM	G. W. Longanecker	NASA-GSFC
PS	R. A. Hoffman	NASA-GSFC
MG	J. R. Holtz	NASA Headquarters
SC	E. R. Schmerling	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
0.8-25 keV Electron-Proton Analyzer	OI	D. J. Williams	NOAA-ERL
	OI	J. F. Arens	NASA-GSFC
	OI	L. R. Davis	NASA-GSFC
	OI	D. S. Evans	NOAA-ERL
	PI	R. A. Hoffman	NASA-GSFC
	OI	A. Konradi	NASA-JSC
	OI	J. H. Trainor	NASA-GSFC
	OI	J. M. Williamson	NASA-GSFC
25-872 keV Proton + Alpha Detector	PI	T. A. Fritz	NOAA-ERL
35-400 keV Electron-SS Detector	PI	D. J. Williams	NOAA-ERL
Fluxgate Magnetometers	PI	L. J. Cahill, Jr.	University of Minnesota
Search Coil Magnetometers	PI	L. J. Cahill, Jr.	University of Minnesota
Direct Current Electrical Field Measurements	OI	D. A. Gurnett	University of Iowa
	PI	N. C. Maynard	NASA-GSFC
Alternate Current Electrical Field Measurements	PI	D. A. Gurnett	University of Iowa
	OI	N. C. Maynard	NASA-GSFC

ARIEL 4 (UK 4)

Launch Vehicle – Scout. Same as Explorer 42.

Spacecraft Description – A cylinder 30 inches in diameter and 3 feet high. Two experiment dipole aerials and four telemetry antennas were mounted on top, and four solar panels supporting two additional experiment loop antennas were deployed from base plate. Weight: 220 pounds.

Project Objectives – Fourth satellite in a joint United States/United Kingdom space program designed to study the interactions between plasma, charged particle streams and EM in the topside atmosphere.

Spacecraft Payload – Five experiments: Molecular oxygen, electron density and temperature, galactic and terrestrial radio noise, VLF radiation and particles. Spacecraft was spin-stabilized at 30 rpm. Communication system included PRM/PM telemetry with 0.25-watt transmitter and data storage capability. Power was supplied by 7,008 n-on-p solar cells and nickel-cadmium batteries. Passive thermal control was employed.

Project Results – Ariel 4 was launched from the Western Test Range in California December 11, 1971, and placed into a 300-mile orbit. All experiments operated normally.

Major Participants – Project management: U.K. Science Research Council. Project technical direction: Royal Aircraft Establishment. Spacecraft prime contractor: British Aircraft Corp. Principal subcontractor: GEC Electronics. Experiments: Meteorological Office, Radio and Space Research Station and the universities of Birmingham, Manchester, Sheffield, and Iowa. Launch vehicle prime contractor: Ling-Temco-Vought.

Key Spacecraft Personnel		Affiliation
PM	J. Smith	Unknown
PM	H. L. Eaker	Unknown
PS	R. Dalziel	Appleton Laboratory
PS	D. S. Evans	NOAA-ERL
PS	G. F. Pieper	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Langmuir Probe	PI	A. P. Willmore	University of Birmingham
MHz Band Radio Noise (E-F)	PI	F. G. Smith	University of Cambridge
	OI	R. Dalziel	Appleton Laboratory
	OI	V. A. W. Harrison	University of Manchester
	OI	D. Walsh	University of Manchester
VLF/ELF Propagation	PI	T. R. Kaiser	University of Sheffield
Low-Energy Charged Particles	PI	L. A. Frank	University of Iowa
	OI	J. D. Craven	University of Iowa
	OI	D. M. Yeager	University of Iowa
	OI	M. A. Schield	University of Iowa
VLF Impulse (Spherics) Center	PI	R. Dalziel	Appleton Laboratory

INTELSAT IV, F-3

Launch Vehicle – Atlas Centaur: Atlas SLV-3C first stage with 402,000 pounds thrust including 60,000-pound sustainer and 1,000-pound thrust vernier control system. Centaur D-1 second stage had 30,000 pounds thrust. Solid propellant SVM-4A third stage (apogee motor mounted in spacecraft) had 10,000 pounds thrust. Height: 132 feet.

Spacecraft Description – Cylinder: 94 inches in diameter, 111 inches high. Total spacecraft height was 17 feet, 6 inches. Solar cells (n on p) formed array covering basic drum providing 570 watts power at beginning of life. Spin rate was approximately 60 rpm. Weight at Launch: 3,100 pounds; in orbit: 1,559 pounds.

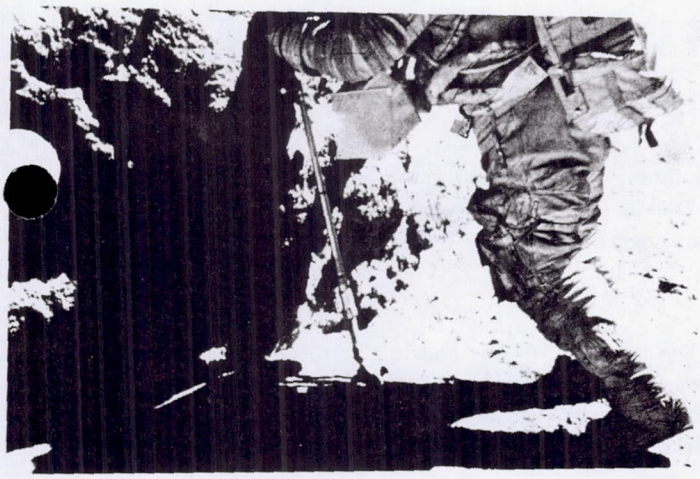
Project Objectives – This fourth-generation satellite increased the capacity of Intelsat's global commercial communications network. Each Intelsat IV could carry a maximum of 9,000 telephone calls or 12 color television broadcasts, with projected circuit mix for voice, video, data and facsimile transmission expected to total about 5,000 channels.

Spacecraft Payload – The communications subsystem, mounted on a mechanically despun platform, included six antennas: two 50-inch dishes for spotbeam transmission to Earth, and a cluster of four conical horn antennas – two for widebeam transmission to Earth and two for receiving from Earth. Antennas were connected to a 12-channel microwave repeater system which provided power amplification for each channel individually. Each 50-inch dish antenna could be directed to almost any point on Earth within line of sight of the satellite. Antenna beamwidth was about 4 degrees. The antennas were steerable in increments of less than 0.1 degree. The global transmit and receive antennas were mounted vertical to the spin axis and directly behind the twin dish antennas, and had a beamwidth of 17 degrees to provide broader coverage. Effective isotropic radiated power at beam center was 37.7 dbw for spotbeam and 22 dbw for widebeam. The communications subsystem received at 5932 to 6418 MHz and transmitted at 3707 to 4192 MHz with a total useable bandwidth of 432 MHz over 12 channels. The satellite also carried omnidirectional command-receive and telemetry-transmit antennas. Station keeping was by two redundant hydrazine half systems, each with two axial, radial and spin-up jets.

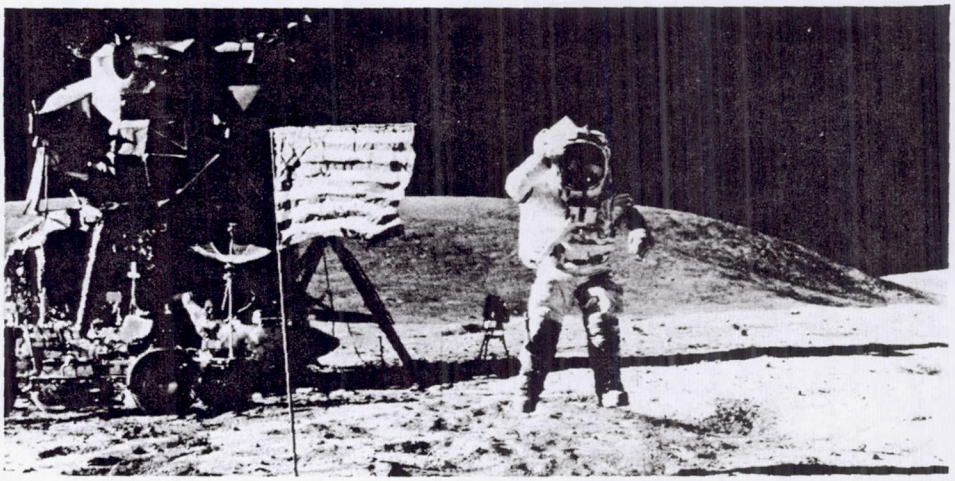
Project Results – Flight 3 was launched December 19, 1971, into synchronous orbit and positioned over the Atlantic at 19.5°W. Long.

Major Participants – Spacecraft management: Communications Satellite Corp. Spacecraft prime contractor: Hughes Aircraft. Launch vehicle management: NASA Lewis. Launch vehicle prime contractor: General Dynamics. Apogee motor: Aerojet-General. Twelve major suppliers from 10 countries made up the international contractor team.

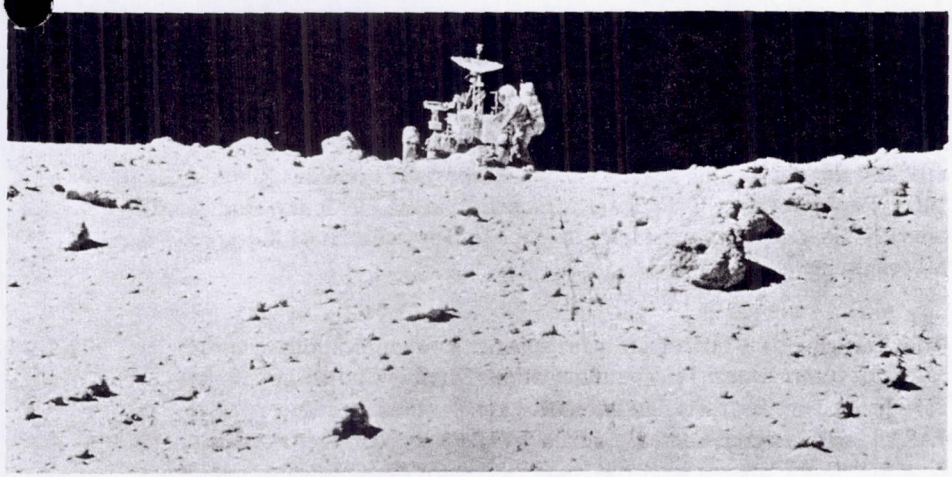
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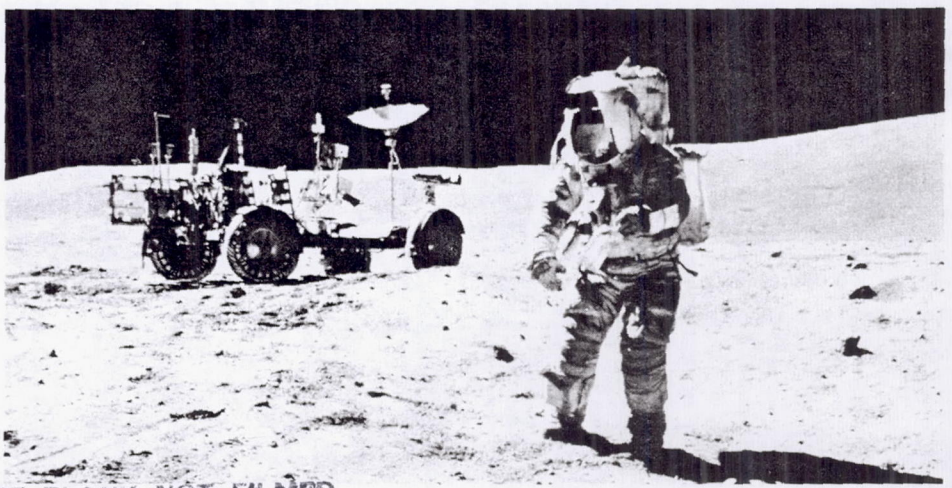
Apollo XVI astronauts explore lunar terrain.



Above: Astronaut John W. Young examines large lunar boulder; he salutes the U.S. flag, right.



Astronaut Charles M. Duke works on lunar rover amidst small rocks and boulders scattered around the lunar landscape.



With rover parked, Young walks on lunar surface during NASA's fifth manned voyage to the Moon.

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INTELSAT IV F-4 and F-5

Launch Vehicle – Atlas-Centaur: Atlas booster developed 402,000 pounds with two 171,000-pound booster engines and one 60,000-pound sustainer engine. Centaur stage's two engines developed 15,000 pounds thrust each. Combination stands 132 feet high.

Spacecraft Description – Drum-shaped; 17 feet high, eight feet in diameter. Weight at launch, 3,123 pounds; weight in orbit, 1,587 pounds. Body was surrounded by 45,012 solar cells to provide approximately 570 watts of electric power. Solid-propellant SVM-4A apogee kick motor mounted on spacecraft develops 10,000 pounds thrust.

Project Objectives – This fourth-generation satellite increased the capacity of Intelsat's global commercial communications network. Each Intelsat 4 spacecraft could carry 5,000 to 6,000 two-way telephone calls or 12 channels of color television.

Spacecraft Payload – The communications subsystem, mounted on a mechanically despun platform, included six antennas: two 50-inch dishes for spotbeam transmission to Earth, and a cluster of four conical horn antennas – two for widebeam transmission to Earth, two for reception from Earth. Antennas were connected to a 12-channel microwave repeater system that provided power amplification for each channel individually. Each 50-inch dish antenna could be directed to any spot on Earth within line of sight of the spacecraft.

Project Results – Flight 4 was launched from Cape Kennedy, Fla., Jan. 22, 1972. Initial orbit was highly elliptical (22,827 miles by 8,740 miles). After checkout the spacecraft was moved to geosynchronous orbit and stationed above the Gilbert Islands in the central Pacific Ocean. Flight 4 was on station in time to broadcast television news reports of President Nixon's visit to Peking, China. Flight 5 was launched June 13, 1972, also from Cape Kennedy. It was placed on station over the Indian Ocean at 61.4 degrees east longitude.

Major Participants – Spacecraft management. Communications Satellite Corp., for International Telecommunications Satellite Consortium. Spacecraft prime contractor, Hughes Aircraft. Launch vehicle management, NASA Lewis Research Center. Launch vehicle prime contractor, General Dynamics/Convair; apogee motor, Aerojet-General. Twelve major suppliers from 10 countries made up the international contractor team.

HEOS A-2

Launch Vehicle – Delta L. Long-tank Delta booster with three solid strapons produced 325,000 lbs. thrust. Second stage was IRFNA/UDMH fueled with 7,700 lbs. of thrust. FW-4D solid motor third stage produced 5,700 lbs. of thrust. Radio guided. Height: 106 ft.

Spacecraft Description – HEOS (Highly Eccentric Orbit Satellite) was a drum-like 16-sided bus with antenna and experiment booms extending from the upper surface. Diameter was 52 inches and height was 94 inches including booms. Spacecraft weight was 258 pounds, including 67 pounds of scientific payload.

Project Objectives – Investigation of particles and micrometeorites in space, of Earth's magnetosphere in high latitudes, and the magnetic belt in the region of the northern "neutral point" where particles are believed to enter the radiation belts.

Spacecraft Payload – HEOS A-2 carried seven experiments provided by various European organizations: magnetic field measurement; plasma measurement; solar VLF observation; particle counter telescope; high-energy electron measurement; solar wind measurement; micrometeorite detector.

Project Results – HEOS A-2 was launched January 31, 1972 from the Western Test Range into a highly elliptical polar orbit 151,287 by 258 miles. All experiments were switched on and working satisfactorily by the end of the first week.

Major Participants – Program management, European Space Research Organization (ESRO); Spacecraft, prime contractor; Messerschmitt-Bolkow-Blohm; Experimenters: Imperial College, London; University of Rome; Danish Space Research Institute; European Space Research and Technology Centre, the Netherlands; Centre D'Etudes Nucleaires, Saclay, and University of Milan; Max Planck Institute, Garching; Max Planck Institute, Heidelberg. Launch operations: NASA. Launch vehicle prime Contractor, McDonnell Douglas.

PIONEER F

Launch Vehicle – Atlas-Centaur with TE-M-364-4 third stage weighing 2,510 pounds and developing 14,800 pounds thrust, boosting the spacecraft to 31,122 miles per hour top speed.

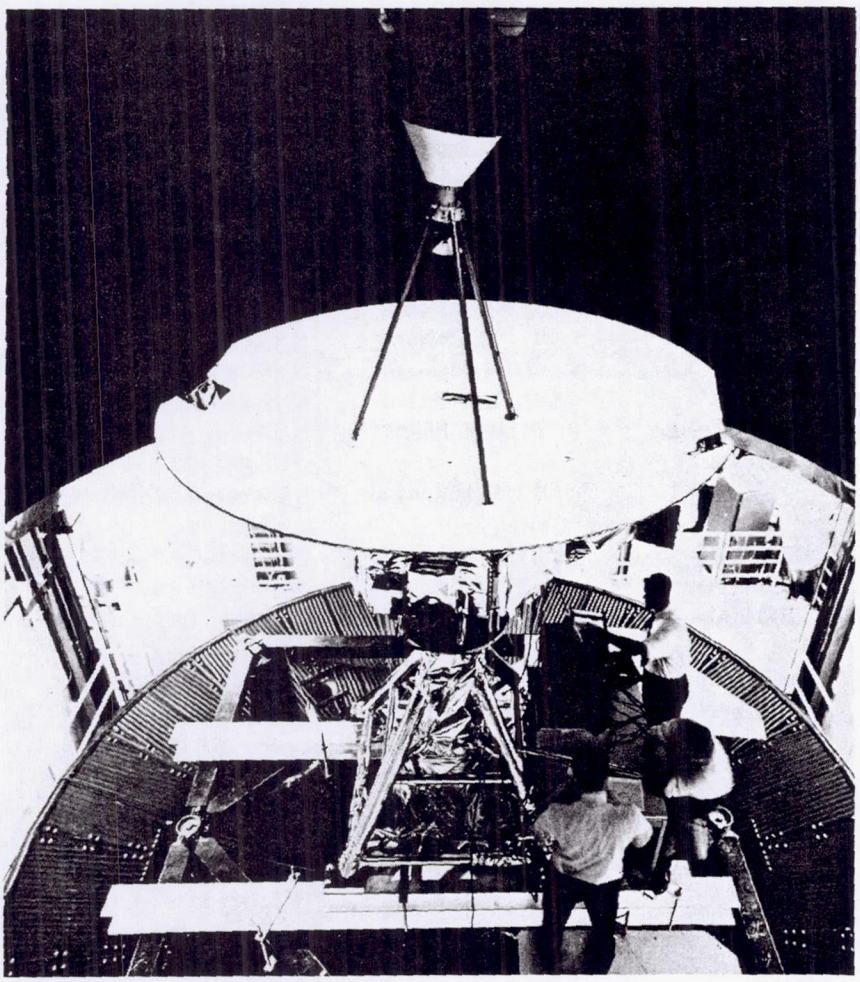
Spacecraft Description – The spacecraft equipment compartment was a 14-inch-deep flat box, top and bottom of which was regular hexagons 28 inches on a side. One side joined to a smaller box also 14 inches deep whose top and bottom are irregular hexagons. The smaller box contained 37 pounds of on-board experiments. Attached to the hexagonal front face of the equipment compartment was a 9-foot-diameter, 18-inch-deep antenna. High gain antenna feed and medium-gain antenna horn were mounted at the focal point of the antenna dish on three struts projecting about four feet forward of the rim of the dish. The low-gain antenna extended about 2.5 feet behind the equipment compartment. Two three-rod trusses, 120 degrees apart, project from two sides of the equipment compartment, to deploy the RTG power sources about 10 feet from the center of the spacecraft. A third boom, 120 degrees from each of the other two, projected from the experiment compartment and positioned the magnetometer sensor 21.5 feet from the spacecraft center. At the rim of the antenna dish was a sun sensor. A star sensor looked through an opening in the equipment compartment and was protected from sunlight by a hood. Both compartments had aluminum frames with bottoms and side walls of aluminum honeycomb sandwich. Rigid external tubular trusswork supported the dish antenna, three pairs of thrusters located near the rim of the dish, boom mounts, and launch vehicle attachment ring. The spacecraft was spin-stabilized at 4.8 rpm. Total weight of Pioneer 10 at launch was 570 pounds, including 65 pounds of scientific instruments. RTC's provided 120 watts of power to the spacecraft and its experiments.

Project Objectives – To investigate Jupiter and its environment, the asteroid belt, the interplanetary medium perhaps as far out as Saturn's orbit, 2 billion miles from the Sun, then to escape the solar system, the first man-made object to do so.

Spacecraft Payload – Eleven instruments and the spacecraft radio, which was used to conduct two experiments (celestial mechanics and S-band occultation). The instruments included a meteoroid detector, an asteroid/meteoroid detector, a plasma analyzer, a helium vector magnetometer, a charged-particle detector, a cosmic-ray telescope, a geiger-tube telescope, a trapped-radiation telescope, an ultraviolet photometer, an infrared radiometer and an imaging photo-polarimeter. The plasma analyzer, cosmic-ray telescope, asteroid/meteoroid telescopes, meteoroid sensors and the magnetometer sensors are mounted outside the instrument compartment.

Project Results – Pioneer 10 was successfully launched March 3, 1972, from Kennedy Space Center, Fla. It crossed the moon's orbit 11 hours after launch. It entered the asteroid belt July 15, 1972 and emerged unscathed Feb 15, 1973, after a seven-month transit. Planet encounter was expected on Dec. 3, 1973, and flyby duration was scheduled to last for one week.

Major Participants – Pioneer-Jupiter program was directed by the Office of Space Science, NASA Headquarters; Project management, NASA Ames Research Center; Spacecraft prime contractor, TRW Systems group; Launch vehicle management, NASA Lewis Research Center; Launch vehicle prime contractors, General Dynamics/Convair (Atlas-Centaur) and Thiokol, Inc., TE-M364-4 third stage.



Pioneer-F being raised into space simulation chamber prior to launch. The satellite was to take the first closeup look of Jupiter and also was expected to explore a curving strip of space 620 million miles long, extending from the Earth's orbit to Jupiter.

Key Spacecraft Personnel		Affiliation
PM	C. F. Hall	NASA-ARC
PS	J. H. Wolfe	NASA-ARC
MG	F. D. Kochendorfer	NASA Headquarters
SC	A. G. Opp	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
3-Axis Helium Magnetometer	PI	E. J. Smith	NASA-JPL
	OI	D. S. Colburn	NASA-ARC
	OI	P. Dyal	NASA-ARC
	OI	C. P. Sonett	University of Arizona
	OI	P. J. Coleman, Jr.	University of California, Los Angeles
	OI	L. Davis, Jr.	California Institute of Technology
	OI	D. E. Jones	Brigham Young University
Charged Particle Composition	PI	J. A. Simpson	University of Chicago
	OI	J. J. O'Gallagher	University of Maryland
	OI	A. Tuzzolino	University of Chicago
Asteroid Astronomy	PI	R. K. Soberman	General Electric Company
	OI	H. A. Zook	NASA-JSC
Meteoroid Detector	PI	W. H. Kinard	NASA-LARC
	OI	R. E. Turner	NASA-MSFC
	OI	J. M. Alvarez	NASA-LARC
	OI	D. H. Humes	NASA-LARC
	OI	R. L. O'Neal	NASA-LARC
Jovian Trapped Particles	PI	R. W. Fillius	University of California, San Diego
	OI	C. E. McIlwain	University of California, San Diego
Ultraviolet Photometer, 200-800A	PI	D. L. Judge	University of Southern California
	OI	R. W. Carlson	University of Southern California
Image Photo Polarimeter	PI	T. Gehrels	University of Arizona
	OI	D. L. Coffeen	NASA-GISS
	OI	J. Hameen-Anttila	University of Arizona
	OI	C. E. Kenknight	University of Arizona
	OI	R. F. Hummer	Santa Barbara Research Center
	OI	M. G. Tomasko	University of Arizona
	OI	W. Swindell	University of Arizona
Infrared Radiometer	PI	A. P. Ingersoll	California Institute of Technology
	OI	G. Neugebauer	California Institute of Technology
	OI	S. C. Chase, Jr.	Santa Barbara Research Center

Experiment	Experiment Personnel		Affiliation
Celestial Mechanics	PI	J. D. Anderson	NASA-JPL
	OI	G. W. Null	NASA-JPL
S-Band Occultation	PI	A. J. Kliore	NASA-JPL
	OI	G. Fjeldbo	NASA-JPL
	OI	D. L. Cain	NASA-JPL
	OI	B. L. Seidel	NASA-JPL
	OI	S. I. Rasool	NASA Headquarters
Jovian Charged Particles	PI	J. A. Van Allen	University of Iowa
Charged Particle Telescope	PI	F. B. McDonald	NASA-GSFC
	OI	K. G. McCracken	CSIRO
	OI	W. R. Webber	University of New Hampshire
	OI	F. C. Roelof	Applied Physics Laboratories
	OI	J. H. Trainor	NASA-GSFC
	OI	B. J. Teegarden	NASA-GSFC
2 Quadrosphere Analyzers	PI	J. H. Wolfe	NASA-ARC
	OI	L. A. Frank	University of Iowa
	OI	R. Lust	MPI Headquarters
	OI	D. S. Intriligator	University of Southern California
	OI	D. D. McKibbin	NASA-ARC
	OI	V. T. Zavientseff	NASA-ARC
	OI	F. L. Scarf	TRW Systems Group
	OI	H. R. Collard	NASA-ARC
	OI	W. C. Feldman	Los Alamos Science Laboratory
	OI	Z. A. Smith	NOAA-SEL
Zodiacal Light Photometer	PI	J. L. Weinberg	Space Astronomy Laboratory
	OI	M. S. Hanner	NASA-JPL
Imaging of Jupiter	PI	T. Gehrels	University of Arizona
	OI	D. L. Coffeen	NASA-GISS
	OI	J. Hameen-Anttila	University of Arizona
	OI	W. Swindell	University of Arizona
	OI	R. F. Hummer	Santa Barbara Research Center
	OI	C. E. Kenknight	University of Arizona
	OI	J. L. Weinberg	Space Astronomy Laboratory

TD-1 (ESRO)

Launch Vehicle – Delta N. Same as HEOS A2 launch vehicle, without third stage. Last use of radio guidance system. Height: 106 ft.

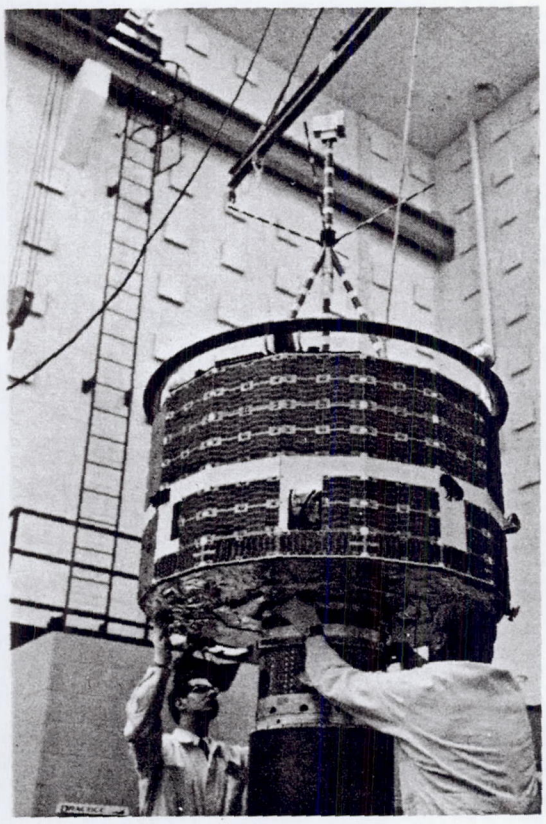
Spacecraft Description – A crate-like spacecraft 7 feet high and 3 feet at the base. Two pairs of solar panels extend from the sides. Total weight was 1038 pounds, including 319 pounds of payload.

Project Objectives – Advanced Western European satellite designed to return data on high-energy emissions from stellar and galactic sources, and from the sun.

Spacecraft Payload – Seven scientific experiments or instruments, including S2/68, a fixed telescope to scan the sky in the 1,300 – 3,000 Angstrom region; S59, a telescope operating in three bands between 2,000 and 3,000 Angstroms; S67, instrument to measure atomic particles; S77, X-Ray spectrometer; S88, solar gamma ray detector; S100, instrument to measure solar particles in the 20 – 700 keV range; S133, celestial gamma radiometer.

Project Results – TD-1A was launched from the Western Test Range on March 12, 1972, into a near-polar 334 by 330 mile orbit. Inclination was 95.7 degrees. The orbit was planned to keep the spacecraft in sunlight continuously for six months. Instruments returned acceptable data until tape recorder No. 2 malfunctioned on April 19 and tape recorder No. 1 began deteriorating on May 10. Data return of only 25 per cent was increased to more than 50 per cent by August 17 increasing real-time monitoring by tracking stations. Spacecraft went into eclipse after six months planned operational lifetime and was spin-stabilized into a hibernation period for possible revival in 1973.

Major Participants – Project management, ESRO; Prime spacecraft contractor, Engins Matra (France); Experiments: S2/68, British Science Research Council and Univ. of Liege; S59, Univ. of Utrecht; S67 and S77, Centre for Nuclear Studies; S88, Univ. of Milan; S100, Univ. of Utrecht; S133, Centre for Nuclear Studies, Max-Planck Institute for Extraterrestrial Physics, and Univ. of Milan. Launch vehicle, McDonnell Douglas. Launch operations: NASA.



The European Space Research Organization's (ESRO) Highly Eccentric Orbit Satellite (HEOS-A2) during its final assembly and checkout tests.

APOLLO XVI, P&F Subsatellite

Launch Vehicle – Saturn V (SA-511). Similar to Apollo XV vehicle. S-IC first stage, with five F-1 engines burning RP-1 (kerosene) fuel and liquid oxygen, produced 7,723,726 pounds of thrust at liftoff. S-II second stage was powered by five J-2 engines burning liquid hydrogen and liquid hydrogen, produced about 1,150,000 pounds of thrust during flight. S-IVB third stage with a single gimballed J-2 engine produced about 207,000 pounds of thrust during flight and was restarted once for translunar injection. Only significant change to SA-511 was a doubling of the retrorocket motors, to eight, on the S-IC to give a greater safety margin during separation. Total weight of the Apollo XVI stack at ignition was 6,406,363 pounds.

Spacecraft Description – Second of the "J" series; essentially identical to Apollo XV and configured for extended mission duration, remote sensing from lunar orbit, and long-distance surface traverses. Scientific Instrument Module (SIM) was included in the service module. Total spacecraft weight at launch was 116,363 pounds: command module "Casper" 12,874 pounds, service module 54,044 pounds, lunar module "Orion" 36,218 pounds, spacecraft-LM adapter (SLA) 4,059 pounds, launch escape system 9,167 pounds.

P&F (Particles and Fields) Subsatellite: Hexagonal: 31 inches high and 14 inches in diameter, spin-stabilized at 12 rpm. Weight: 80 pounds. Solar arrays provided 25 watts of power.

Project Objectives – Three primary objectives were (1) to inspect, survey, and sample materials and surface features at a selected landing site in the Descartes region; (2) emplace and activate surface experiments; (3) conduct inflight experiments and photographic tasks from lunar orbit. Additional objectives included performance of experiments requiring zero gravity and engineering evaluation of spacecraft and equipment. The Descartes landing site is in a highlands region of the moon's southeast quadrant, characterized by hilly, grooved, furrowed terrain. It was selected as an outstanding location for sampling two volcanic constructional units of the highlands – the Cayley formation and the Kant Plateau. The Apollo lunar surface experiments package (ALSEP) was the fourth such station to become operational, after Apollos XII, XIV, and XV. Orbital science experiments were concentrated in an array of instruments and cameras in the SIM bay. Hand-held Hasselblad 70mm still and Mauer 16mm motion cameras were used by the crew. Minor changes in surface EVA equipment were evaluated – a stronger clutch spring in the television camera drive mechanism to eliminate aiming problems experienced on Apollo XV, longer seat belts on the lunar rover for better astronaut retention, continuous fluting of drill bits to eliminate bit binding due to extracta jamming, and the addition of a treadle and jack to aid in drill core removal from the lunar subsurface. A significant addition to surface objectives was an ultraviolet stellar camera to return photography of the Earth and celestial regions in spectral bands not seen from Earth. Evaluation of the lunar rover through a "Grand Prix" exercise consisting of S-turns, hairpin turns, and hard stops also was to be conducted. A final orbital objective was to launch a subsatellite into lunar orbit from the CSM shortly before transearth injection.

P&F Subsatellite: To investigate the moon's mass and gravitational variations, particle composition of space near the moon, and interaction of the moon's magnetic field with that of Earth.

Spacecraft Payload – Similar to Apollo XV in the amount of scientific instrumentation/exploration equipment aboard. The fourth ALSEP station included the final passive seismic experiment, completing a four-site lunar network of seismometers for continuous measurement of moonquakes and meteoroid impacts; lunar surface magnetometer for measuring the magnetic field at the lunar surface; heat flow experiment to measure the steady-state heat flow from the lunar interior; and the active seismic experiment to provide data on the physical structure and bearing strength of the lunar surface. A percussive drill for drilling holes in the lunar regolith for placement of the heat flow probes and for obtaining deep core samples again was used. Experiments independent of ALSEP were geology investigation, a solar wind composition experiment for determining the isotopic makeup of noble gases in the solar wind; a lunar portable magnetometer (LPM) for measuring local variations of the lunar magnetic field; a far ultraviolet camera/spectroscope for mapping concentrations of hydrogen in interplanetary, interstellar, and intergalactic regions; and a cosmic ray detector mounted on the lunar module descent stage for measuring the charge, mass, and energy of cosmic ray and solar wind particles impacting the four-panel array during translunar coast and on the moon. Experiments in the SIM bay were identical to Apollo XV: gamma-ray spectrometer and X-ray fluorescence to measure lunar surface chemical composition along the orbital ground track; alpha-ray spectrometer to measure alpha particles from radioactive decay of random gas isotopes emitted from the lunar surface; mass spectrometer to measure the composition and distribution of the lunar atmosphere; and the P&F subsatellite. The SIM bay also contained two cameras for orbital photography – a 24-inch panoramic camera and a three-inch mapping camera, plus a laser altimeter for accurately measuring spacecraft altitude for correlation with the mapping photos. The Lunar Roving Vehicle again was used. Crew for Apollo XVI included Spacecraft Commander John W. Young, a Navy Captain making his fourth space flight; Command Module Pilot Ken Mattingly, a Navy Lieutenant Commander; and Lunar Module Pilot Charles M. Duke, an Air Force Lieutenant Colonel. It was the first space flight for both Mattingly and Duke.

P&F Subsatellite: One watt S-band transponder, magnetic core memory unit with 49,152 bit capacity, with a transmit rate of 128 bits per second.

Project Results – Apollo XVI lifted off at 12:54 p.m. EST, April 16, 1972, from Launch Complex 39 at Kennedy Space Center, Florida. Two significant command and service module problems – one enroute to the moon and one in lunar orbit – contributed to a delay in landing and a subsequent early termination of the mission. Erroneous signal indicating guidance system gimbal lock during translunar coast was neutralized by real time programming change instructing spacecraft computer to ignore input. After undocking of Casper and Orion, circularization burn of CSM was delayed when backup circuit caused yaw oscillations of service propulsion system.

Orion landing was held until engineers determined oscillations would not seriously affect CSM steering. Lunar module carrying Young and Duke touched down at Descartes about 276 meters northwest of planned point (8°59′29″S, 15° 30′52″E), about 9:24 p.m. EST April 20, about 5 hours, 43 minutes late. During 71 hours, 2 minutes surface stay, astronauts explored region on three EVA's totaling 20 hours, 14 minutes. First EVA included Rover setup and ALSEP deployment. Heat flow experiment was lost when Young tripped on electronics cable, breaking it. Rover traverse took astronauts west to Flag Crater where they collected samples and photographed the area. Return drive was south of outbound track to Spook Crater where astronauts took first measurement with the lunar portable magnetometer, gathered samples, and took both panoramic and 500-mm telephotography. Just before returning to the lunar module, they deployed the solar wind composition experiment at the ALSEP site. EVA duration was about 7 hours, 11 minutes with 2.5 miles driven in the Rover. Second EVA began with drive south to Stone Mountain, where surface and core samples were collected at two stations in the area of Cinco Craters, along with a trench sample, penetrometer measurements, and photography. Traverse continued west, then north with stops at five additional stations for similar work. One station was deleted from the EVA plan because of time factors. LPM measurements were taken near Cinco. Crew returned to lunar module and ended second EVA after 7 hours, 23 minutes and 6.9 miles on the Rover. Real-time flight planners deleted four stops from the third and final EVA because of time constraint in meeting ascent schedule. Astronauts drove north to North Ray Crater where "House Rock," inside the crater rim, was sampled. Returning south, the crew stopped at "Shadow Rock" for additional sampling, photography, and LPM measurement. Final stop near the LM added samples and core tubes to the collection. Last LPM readings were taken at the Rover parking site along with final rock samples. Closeout including retrieval of SWC and film from far ultraviolet camera/spectroscope completed EVA after 5 hours, 40 minutes. Rover distance was 7.1 miles. During surface stay of Young and Duke, Mattingly orbited the moon with cameras and SIM bay instruments operating. Results verified Apollo XV data and provided information on lunar terrain not previously covered. Lunar liftoff came on time at 8:26 EST, April 23, 1977, in view of the Rover television camera. After normal rendezvous and docking, and transfer of crew, samples, and equipment, the lunar module was jettisoned ;attitude control was lost, eliminating the usual deorbit maneuver and planned impact. Because of problems noted earlier, planners elected to return the mission one day early. During transearth coast, Mattingly took an 83-minute spacewalk to retrieve film cassettes from the SIM bay. Normal entry and landing resulted in splashdown at 0°42′0″S, 156°12′49″W, just before 3 p.m. EST, April 27, 1977. Total mission time was 265 hours, 51 minutes, 5 seconds. Young and Duke collected 209 pounds of samples, and drove the Rover 16.6 miles.

P&F Subsatellite: The orbital shaping maneuver was deleted and the subsatellite was ejected into a highly elliptical orbit, cutting lifetime from one year to about one month. Normal operation continued until May 29, 1977, when it impacted the moon.

Major Participants – Program management: NASA Office of Manned Space Flight. Spacecraft management: NASA Manned Spacecraft Center. CM and SM spacecraft prime contractor: Rockwell International. Principal contractors: SPS, Aerojet-General; ablative heat shield, AVCO; communication and data subsystems, Collins; environmental control system, Garrett. LM spacecraft prime contractor; Grumman. Principal contractors; Primary guidance and navigation system, General Motors (manufacturing) and MIT (technical management); ascent engine, Rockwell International; communications subsystems and radar and control electronics, RCA; descent engine and abort guidance system, TRW. Astronauts' portable life support systems: Hamilton-Standard. Space suits: ILC Industries. Apollo Lunar Surface Experiments Package: Bendix. IU prime contractor: IBM. Apollo-Saturn V technical integration and evaluation: Boeing. Apollo checkout equipment, related engineering and design, quality management, and engineering support: GE. Mission trajectory control and spacecraft system analysis: TRW. Launch vehicle management: NASA Marshall Space Flight Center. First stage prime contractor: Boeing. Second stage: Rockwell International. Third stage: McDonnell Douglas. Launch operations: NASA Kennedy Space Center. Manned Space Flight Network management: Goddard Space Flight Center. Lunar Rover Vehicle prime contractor: Boeing; major subcontractor: Delco Electronics Division of General Motors. P&F Subsatellite management: NASA MSC; prime contractor; TRW. SIM bay management: NASA MSC; integrator; Rockwell International.

Key Spacecraft Personnel	Affiliation
CSM, Apollo XVI	
PM R. Petrone	NASA Headquarters
SC Unknown	Unknown
LM Alsep, Apollo XVI	
MG F. I. Roberson	NASA Headquarters
SC J. B. Hanley	NASA Headquarters
PM W. F. Eichelman	NASA-JSC
PS None Assigned	
Subbat, Apollo XVI	
PM Unknown	Unknown
PS Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
Handheld Photography	PI	F. J. Doyle	U.S. Geological Survey
Panoramic Photography	PI	F. J. Doyle	U.S. Geological Survey
Metric Photography	PI	F. J. Doyle	U.S. Geological Survey
Stellar Photography	PI	F. J. Doyle	U.S. Geological Survey
Laser Altimeter	PI	W. M. Kaula	University of California, Los Angeles
Ultraviolet Photography	PI	T. C. Owen	Illinois Institute of Technology
Apollo XVI			
Gamma-Ray Spectrometer	PI	J. R. Arnold	University of California, San Diego
	OI	A. E. Metzger	NASA-JPL
	OI	L. F. Peterson	University of California, San Diego
	OI	J. I. Trombka	NASA-GSFC
X-Ray Fluorescence	PI	I. Adler	NASA-GSFC
	OI	A. E. Metzger	NASA-JPL
	OI	P. Gorenstein	Harvard College Observatory
	OI	H. Gursky	Harvard College Observatory
	OI	J. I. Trombka	NASA-GSFC
Alpha-Particle Spectrometer	PI	P. Gorenstein	Harvard College Observatory
S-Band Transponder	PI	W. L. Sjogren	NASA-JPL
Mass Spectrometer	PI	J. H. Hoffman	University of Texas, Dallas
Bistatic Radar	PI	H. T. Howard	Stanford University
	OI	V. R. Eshleman	Stanford University
	OI	A. M. Peterson	Stanford University
	OI	B. L. Taylor	Stanford University
Gegenschein Photos	PI	L. Dunkelman	NASA-GSFC
Window Meteoroid	PI	B. G. Cour-Palais	NASA-JSC
	OI	M. L. Brown	Lockheed Electronics
	OI	D. S. McKay	NASA-JSC
Contamination Photography Experiment	PI	G. A. Gary	NASA-MSFC
	OI	P. D. Craven	NASA-MSFC
Biostack	PI	H. Bucker	DFVLR
	OI	G. Horneck	University of Frankfurt
Passive Seismic Experiments	PI	G. V. Latham	University of Texas, Galveston
	OI	F. Press	Massachusetts Institute of Technology
	OI	G. H. Sutton	University of Hawaii

Experiment	Experiment Personnel		Affiliation
Active Seismic Experiment	PI	R. L. Kovach	Stanford University
	OI	J. S. Watkins	University of Texas, Galveston
Lunar Surface Magnetometer	PI	P. Dyal	NASA-ARC
	OI	C. W. Parkin	NASA-ARC
	OI	C. P. Sonett	University of Arizona
Heat Flow (Failed)	PI	M. G. Langseth	Lamont-Doherty Geological Observatory
Field Geology	PI	W. R. Muehlberger	U.S. Geological Survey
	CO	M. Miller	NASA-JSC
Solar Wind Composition	PI	J. Geiss	University of Berne
Cosmic Ray Detector	PI	R. L. Fleischer	General Electric Company
Portable Magnetometer	PI	P. Dyal	NASA-ARC
Soil Mechanics	PI	J. K. Mitchell	University of California, Berkeley
	CO	M. Miller	NASA-JSC
Far Ultraviolet Camera/Spectrometer	PI	G. R. Carruthers	U.S. Naval Research Laboratory
	OI	T. Page	NASA-JSC
S-Band Transponder	PI	W. L. Sjogren	NASA-JPL
Particle Shadow Layer	PI	K. A. Anderson	University of California, Berkeley
	OI	L. M. Chase	University of California, Berkeley
	OI	P. J. Coleman, Jr.	University of California, Los Angeles
	OI	R. P. Lin	University of California, Berkeley
	OI	J. McCoy	NASA-JSC
	OI	G. Schubert	University of California, Los Angeles
	CO	P. E. Lafferty	NASA-JSC
Magnetometer	PI	P. J. Coleman, Jr.	University of California, Los Angeles
S-Band Transponder	PI	W. L. Sjogren	NASA-JPL

ERTS-A
LANDSAT-1

Launch Vehicle – Delta 900. 480,000-lb. thrust first stage, first to use nine solid strapons (six fire at liftoff). First nitrogen tetroxide-aerozine 50 fueled second stage produced 9,800 lbs. of thrust. First use of new Delta inertial guidance system. Height: 106 ft.

Spacecraft Description – Design was based on the Nimbus meteorological satellites. Main bus was squat cylinder with solar paddles, spacecraft electronics, and attitude and control subsystem mounted atop the superstructure, and payload mounted in a ring structure at the base. Solar arrays were independently drive. Storage batteries power the spacecraft during eclipses. Orbital adjustment system unique to ERTS gave correction capability after injection or periodic trim with one-pound thrusters fueled by hydrazine. Spacecraft weight is 1,965 pounds.

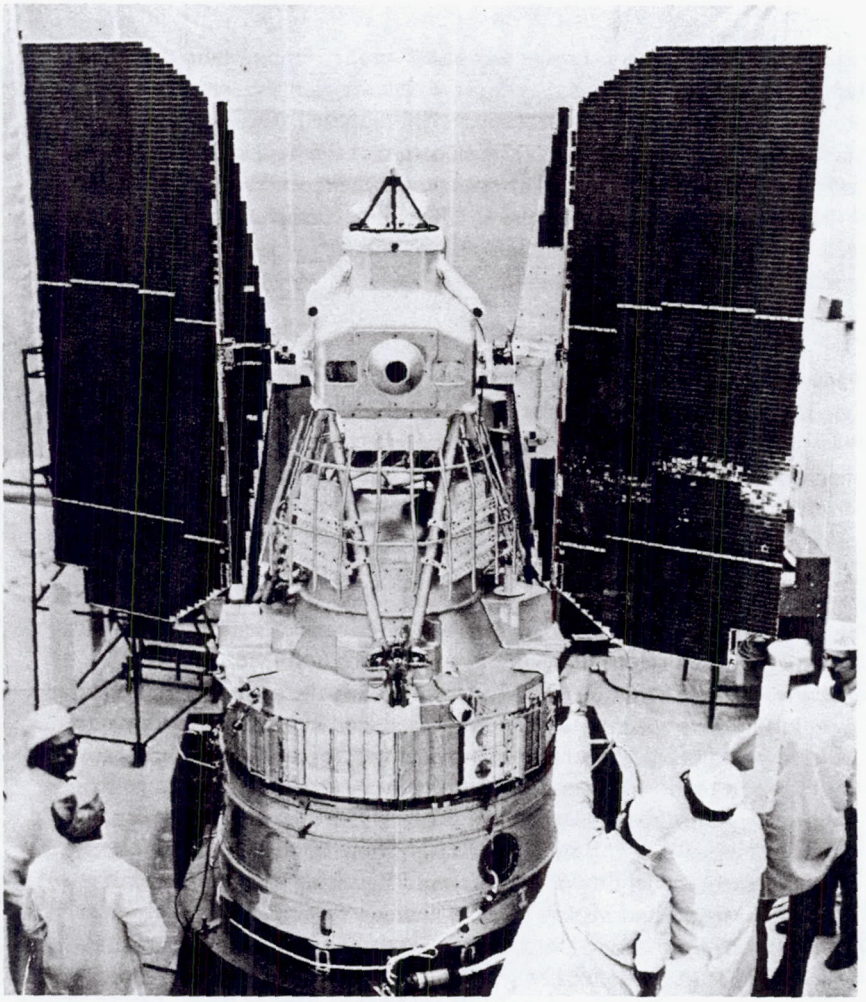
Project Objectives – To demonstrate the usefulness of remote sensing of conditions on the Earth's surface on a global scale and on a repetitive basis. Specifically ERTS was determining what data could be gathered by an unmanned spacecraft, how this data could be interpreted and applied to a diversity of endeavors, and how the information yield could be of economic or social value to commercial, scientific, and government interests.

Spacecraft Payload – Spacecraft carried 485 pounds of sensor, communications, and related electronics equipment. Return beam vidicon (RBV) television system had three cameras, each viewing the same 115-mile-square area, but in three spectral bands – green, red, and near infrared. Cameras were triggered every 25 seconds to provide overlapping frames. Images could be relayed to Earth in near real-time or be stored on video tape for later replay. Multispectral scanner subsystem (MSS) covered a continuous swath 115 miles wide, identical to the RBV viewing area, in four spectral bands – green, red, and two near-infrared. Resulting images were photo-like in appearance and quality. Data collection system (DCS) received transmissions from about 150 remote, unattended units on Earth. Data was relayed at least twice daily to ground stations on such diverse subjects as stream flow, snow depth, soil moisture, and volcanic activity. Two wide band video tape recorders stored images of terrain outside North America for playback to U.S. ground stations.

Project Results – ERTS-A was launched into a near-polar, 570-mile circular orbit from the Western Test Range on July 23, 1972. Data returned surpassed all expectations, both in volume and quality. Discoveries included a 25-mile-diameter geological feature near Reno that may be a meteor crater, water pollution that drifts cohesively off the Atlantic Coast rather than dissipating quickly, and water-bearing rocks in Nebraska, Illinois, and New York. Some equipment problems were encountered but mission objectives were being met. One video tape recorder failed and a power surge affected attitude control jets and the RBV system.

Major Participants – Spacecraft management: Goddard Space Flight Center. Prime contractor: General Electric Company. Multispectral scanner system: Hughes Aircraft Company. RBV and video tape recorders: RCA. Launch Vehicle: McDonnell Douglas.

On July 23, 1972 ERTS-A, the Earth Resources Technology Satellite was launched. It was the first step in the merger of space and remote sensing technology into a system devoted to the more efficient management of the Earth's resources. Its design was based on the highly successful Nimbus weather satellites.



Key Spacecraft Personnel		Affiliation
PM	C. M. Mackenzie	NASA-GSFC
MG	B. T. Nolan	NASA Headquarters
PS	S. C. Freden	NASA-GSFC
SC	R. I. Whitman	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Return Beam Vidicon	PI	O. Weinstein	NASA-GSFC
Camera System	OI	T. M. Ragland	NASA-GSFC
Multispectral Scanner System	PI	J. Arluskas	NASA-GSFC
Data Collection System	PI	J. E. Painter	NASA-GSFC

EXPLORERS 46, 47, 48

Launch Vehicle – Explorer 46: Solid propellant Scout: 101,000-pound thrust Algol II first stage, 61,000-pound thrust Castor II second stage, 21,000-pound thrust Antares II third stage, and the Altair fourth stage. Height: 73 feet. EXPLORER 47: Delta 1640. Similar to ERTS launch vehicle, but with 10-foot extension of first stage and TE 364-4 third stage producing 15,000 lbs. thrust. Height: 116 ft. EXPLORER 48: Scout launch vehicle.

Spacecraft Description – Explorer 46: Windmill-like spacecraft with meteoroid bumper panels deployed from a hexi-cylindrical bus; fourth stage of booster also orbits attached to the spacecraft. Panels were 10.5 feet long. Spacecraft weight 300 pounds. Explorer 47: Drum-shaped 16-sided body with boom-mounted experiment packages and weighing 860 pounds. Explorer 48. Bulbous spark chamber mounted atop a cylindrical control section, with four winged solar panels; spacecraft height was 51 inches, with panels measuring 156 inches tip-to-tip; weight was 410 pounds.

Project Objectives – EXPLORER 46: Meteoroid Technology Satellite designed to provide data on penetration rates in a bumper-protected target and on meteoroid speeds and quantities. EXPLORER 47: Interplanetary Monitoring Platform (IMP-H), an automated space physics laboratory to continue study of interplanetary radiation, solar wind and energetic particle emissions, and magnetic fields in Earth environment from an orbit reaching about halfway to the moon. EXPLORER 48: Small Astronomy Satellite (SAS-B), with single purpose of studying gamma rays.

Spacecraft Payload – EXPLORER 46: More than 300 square feet of bumper target, with pressurized cell detectors to record penetration of the bumper plus main wall. Target was .001-inch stainless steel mounted one-half inch in front of a .002-inch stainless steel main wall. Bumper target was divided into 12 panels, each with eight cells, providing 96 detectors on the spacecraft. In addition, 12 box-shaped meteoroid velocity detectors were mounted around the central hub. Each detector was 8x8x6 inches and provided measuring stations a known distance apart for determining the speed of particles penetrating both walls. SAS-B also carried 64 capacitor detectors to provide data on particle populations in the orbit traveled. EXPLORER 47: IMP-H carried eight particles experiments, two fields experiments, and three plasma experiments. Three engineering tests – monitoring of 12 thermal coatings, monitoring of newly developed integral glass solar cells, and qualification of a new data multiplex unit and a data processing unit – also were included EXPLORER 48: SAS-B single experiment was a 32-level digitized spark chamber gamma-ray telescope mounted in a bulbous dome; sensitivity was about 10 times greater than any gamma ray detector previously orbited.

Project Results — Explorer 46 was launched August 13, 1972, from Wallops Station, Va., into an orbit of 494 by 302 miles inclined at 37.7°. One pair of bumper wings failed to fully deploy. Secondary experiments were suspended to get maximum data from the bumpers. About 20 impacts were recorded through December, 1972. In addition, the capacitor detectors had successfully recorded about 2,000 micrometeoroids in near-Earth space.

Velocity detectors were interrogated during 1973. Explorer 47 was launched September 22, 1972, from Kennedy Space Center into an orbit of 141,383 by 120,960 miles inclined at 17.2°. Instruments were turned on and the spacecraft was expected to operate for at least one year. Explorer 48 was launched November 16, 1972, from the San Marco Equatorial Range into an orbit of 274 x 392 miles inclined at 1.2°. Its gamma ray detector continued to operate flawlessly through 1972.

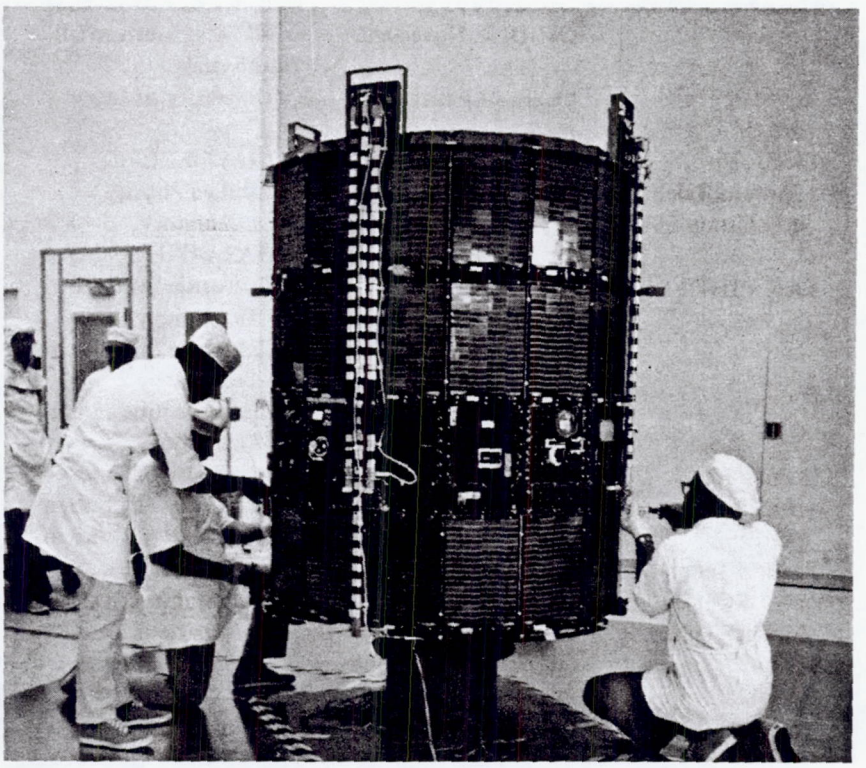
Major Participants – EXPLORER 46: Project management, Langley Research Center; Tracking and Data Acquisition, Goddard Space Flight Center; Launch Operations, Wallops Station; Launch vehicle Prime Contractor, LTV Aerospace Corp. EXPLORER 47: Project management and spacecraft construction, Goddard Space Flight Center; Experiments, cosmic ray, Goddard; cosmic ray, Univ. of Chicago; energetic particles, NOAA; charged particles, Johns Hopkins Univ.; electrons and isotopes, C.I.T.; ion and electron, Univ. of Maryland; solar electrons, Goddard; low energy particles, Univ. of Iowa; magnetic fields, Goddard; plasma wave, TRW Systems; solar wind, Los Alamos Scientific Laboratory; solar wind, M.I.T.; ion composition, Goddard, Launch operations, KSC; Launch vehicle prime contractor, McDonnell Douglas, EXPLORER 48; Project management, spacecraft construction, and experiment, Goddard Space Flight Center; Control section, Johns Hopkins Univ.; Launch operations, Aerospace Research Center, Univ. of Rome; Launch vehicle prime contractor, LTV Aerospace Corp.

Key Spacecraft Personnel		Affiliation
Explorer 46		
CO	R. L. Mitchell	NASA-GSFC
PM	C. V. Woerner	NASA-LARC
PS	W. H. Kinard	NASA-LARC
Explorer 47		
PM	M. A. Davis	NASA-GSFC
PS	J. H. King	NASA-GSFC
CO	J. H. Trainor	NASA-GSFC
MG	J. R. Holtz	NASA Headquarters
SC	E. R. Schmerling	NASA Headquarters
Explorer 48		
PM	M. R. Townsend	NASA-GSFC
PS	C. E. Fichtel	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Explorer 46			
Bpr. Pnls.	OI	W. H. Kinard	NASA-LARC
	PI	D. H. Humes	NASA-LARC
Metro Velocity	PI	J. M. Alvarez	NASA-LARC
	OI	P. D. Burbank	NASA-JSC
	OI	W. H. Kinard	NASA-LARC
Impact Flux	OI	W. H. Kinard	NASA-LARC
	PI	J. M. Alvarez	NASA-LARC
Explorer 47			
Tri-Axis Magnetometer	PI	N. F. Ness	NASA-GSFC
	OI	C. S. Scearce	NASA-GSFC
	OI	J. B. Seek	NASA-GSFC
Solar Plasma, Faraday Cup	PI	H. S. Bridge	Massachusetts Institute of Technology
	OI	A. J. Lazarus	Massachusetts Institute of Technology
	OI	J. H. Binsack	Massachusetts Institute of Technology
	OI	E. F. Lyon	Massachusetts Institute of Technology
Solar Ions + Electrons, 100keV	PI	G. Gloeckler	University of Maryland
	OI	C. Y. Fan	University of Arizona
	OI	D. K. Hovestadt	MPI-Extraterrestrial Physics
Lepedea 25eV-50keV	PI	L. A. Frank	University of Iowa
Electrons + Photons Telemetry Group 50keV	PI	D. J. Williams	NOAA-ERL
	OI	C. O. Bostrom	Applied Physics Laboratory
	OI	J. H. Trainor	NASA-GSFC
Elec. + H+He Solid	PI	F. C. Stone	California Institute of Technology
	OI	R. E. Vogt	California Institute of Technology
	CO	W. E. Althouse	California Institute of Technology
Cosmic Ray Nuclear Composition	PI	J. A. Simpson	University of Chicago
	OI	M. Garcia-Munoz	University of Chicago
	CO	G. Lentz	University of Chicago
Particle Telemetry + Geiger Mueller Tubes	PI	S. M. Krimigis	Applied Physics Laboratory
	OI	T. P. Armstrong	University of Kansas
	OI	J. A. Van Allen	University of Iowa
Cosmic Ray (E vs De/Dx)	PI	F. B. McDonald	NASA-GSFC
	OI	D. E. Hagge	Unknown
	OI	B. J. Teegarden	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Plasma Electro-magnetic Analyzer	PI	S. J. Bame	Los Alamos Scientific Laboratory
	OI	J. R. Asbridge	Los Alamos Scientific Laboratory
Plasma Wave Experiment	PI	F. L. Scarf	TRW Systems Group
	OI	G. M. Crook	Gaines M. Crook Associates
	OI	I. M. Green	TRW Systems Group
	OI	R. W. Fredericks	TRW Systems Group
Ion Composition	PI	K. W. Ogilvie	NASA-GSFC
Solar Electrons	PI	T. L. Cline	NASA-GSFC
Deuterium in Solar W.	PI	F. Scherb	University of Wisconsin
Low Energy Solar Electrons	PI	K. A. Anderson	University of California, Berkeley
Electrostatic Fields	PI	T. L. Aggson	NASA-GSFC
	OI	J. P. Heppner	NASA-GSFC
Explorer 48			
High-Energy Gamma-Ray Telescope	PI	C. E. Fichtel	NASA-GSFC

Advanced Interplanetary Monitoring Platform, Explorer 47/IMP-H, is readied for launch.



OAO 3 (Copernicus)

Launch Vehicle – Atlas-Centaur, same as Intelsat IV.

Spacecraft Description – A 4,900-pound, octagonal cylinder seven feet wide and 10 feet long. Two paddle-like solar arrays gave it an overall width of 21 feet when they were deployed. It was three-axis stabilized with a pointing accuracy of less than 0.1 second of arc – most precise ever achieved by a spacecraft. The system used four gimbaled star trackers, an inertial reference unit to facilitate slew maneuvers and maintain pointing accuracy, and a system of stabilizing gyros. More than one-fifth (1,000 pounds) of the total weight was scientific payload.

Project Objectives – To study interstellar absorption of hydrogen, oxygen, carbon, silicon and other common elements in the interstellar gas, and to investigate ultraviolet radiation emitted from so-called young hot stars in wavelength regions between 930 Angstroms and 3,000 Angstroms.

Spacecraft Payload – The Princeton Experiment Package (PEP), in the central experiment tube, included a 10-foot-long ultraviolet telescope, a 32-inch mirror, an ultraviolet spectrometer, and sensors for the telescope guidance system, able to view stars as faint as seventh magnitude. Scientific objectives of the PEP included study of the abundance and temperature distribution of interstellar gas and study of the structure of stellar atmospheres of young hot stars. The University College of London Experiment Package, mounted in an upper bay of the main body, consisted of three small telescopes and a collimated proportional counter. It permitted pinpointing many recently discovered X-ray sources more precisely.

Project Results – Launched August 21, 1972 from Kennedy Space Center. Preliminary results from the PEP included detection of large quantities (more than 10 percent) of molecular hydrogen in the denser interstellar dust clouds; (hydrogen also occurs in atomic form in these regions); observation of surprisingly large amounts of deuterium – heavy hydrogen – in interstellar dust clouds; (Deuterium is a basic element for fusion in the formation of stars, and current theories suggest that much of it should already have been used up. These theories may have to be revised in view of the abundance of deuterium observed); determination that lesser amounts of heavier elements exist in clouds than in the Sun; determination that some solid particles or dust grains in interstellar clouds are smaller than believed previously – some less than one-millionth of an inch in diameter. Preliminary results from the University College of London Experiment Package indicate that the period of rotation of the Cygnus X-1 binary system is increasing at a rate perceptible after the first month of operations.

Major Participants – The OAO program was directed by the Office of Space Science, NASA Headquarters; Project management, Goddard Space Flight Center; spacecraft prime contractor, Grumman Aerospace Corp.; PEP prime contractors, Sylvania Electronics Systems and Perkin-Elmer Corp.; UCL package, Pye Telecommunications, Elliott Brothers and Rank-Taylor-Hobson, all of the United Kingdom; launch vehicle management, NASA Lewis Research Center; launch vehicle prime contractor, General Dynamics/Convair.

Key Spacecraft Personnel		Affiliation
PM	J. Purcell	NASA-GSFC
PS	J.E. Kupperian, Jr.	NASA-GSFC
MG	M.E. McDonald	NASA Headquarters
SC	E.J. Weiler	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Reflector Telescope, 800-3000A	PI	L. Spitzer	Princeton University
	OI	J. Rogerson, Jr.	Princeton University
Stellar X-Ray Emission, 3-60A	PI	R. L. F. Boyd	University College London
	OI	P. W. Sanford	University College London

ITOS-D (NOAA-2)
AMSAT-OSCAR-6

Launch Vehicle – Delta 300. Similar to ERTS launch vehicle, but with only three solid strap-ons.

Spacecraft Description – ITOS-D: Box-shaped (40 by 40 by 49 inches), about 14 feet wide with its three solar panels deployed. Earth-oriented and three-axis stabilized. A momentum wheel assembly controlled pitch attitude. Total solar array area of about 49 square feet provided 250 watts of power. Spacecraft weight was 736 pounds.

AMSAT-OSCAR-6: Orbiting Satellite Carrying Amateur Radio. Nonmodular structured spacecraft is 17 inches long, 12 inches wide and six inches high. Nickel-cadmium batteries provided 24 volts direct current at 3.5 watts. Spacecraft weight was 35 pounds.

Project Objectives – ITOS-D: To expand the operational capability of the National Oceanic and Atmospheric Administration's weather system for use in day-to-day real-time weather analysis. ITOS-D provided global coverage of the Earth's atmosphere and oceans twice each day, crossing the equator at 9 a.m., local sun time, southbound; and 9 p.m., local sun time, northbound.

AMSAT-OSCAR-6: Sixth in series of amateur-built and operated satellites designed to retransmit Morse code messages.

Spacecraft Payload – ITOS-D: Although similar in appearance to previous ITOS models, it was the first to fly with no onboard cameras. It depended entirely on scanning radiometers for imagery. Two instruments were the same as on past spacecraft: a two-channel scanning radiometer and a solar proton monitor. New on ITOS-D was a vertical temperature profile radiometer and a very-high-resolution radiometer. The VHRR reported the cloud cover and sea surface temperature. The VTPR measured infrared energy radiated at six levels of the atmosphere and at the sea surface. The spacecraft could transmit in real time or store information for later transmission.

AMSAT-OSCAR-6: A two-to-ten-meter linear translator and a 24-channel Morse code telemetry encoder. Also onboard was CODESTORE, a shift-register memory device capable of storing Morse code for repeated transmission on the 29.450 MHz CW beacon. CODESTORE's memory length was 768 bits, sufficient to permit storage of about 15 words in Morse code.

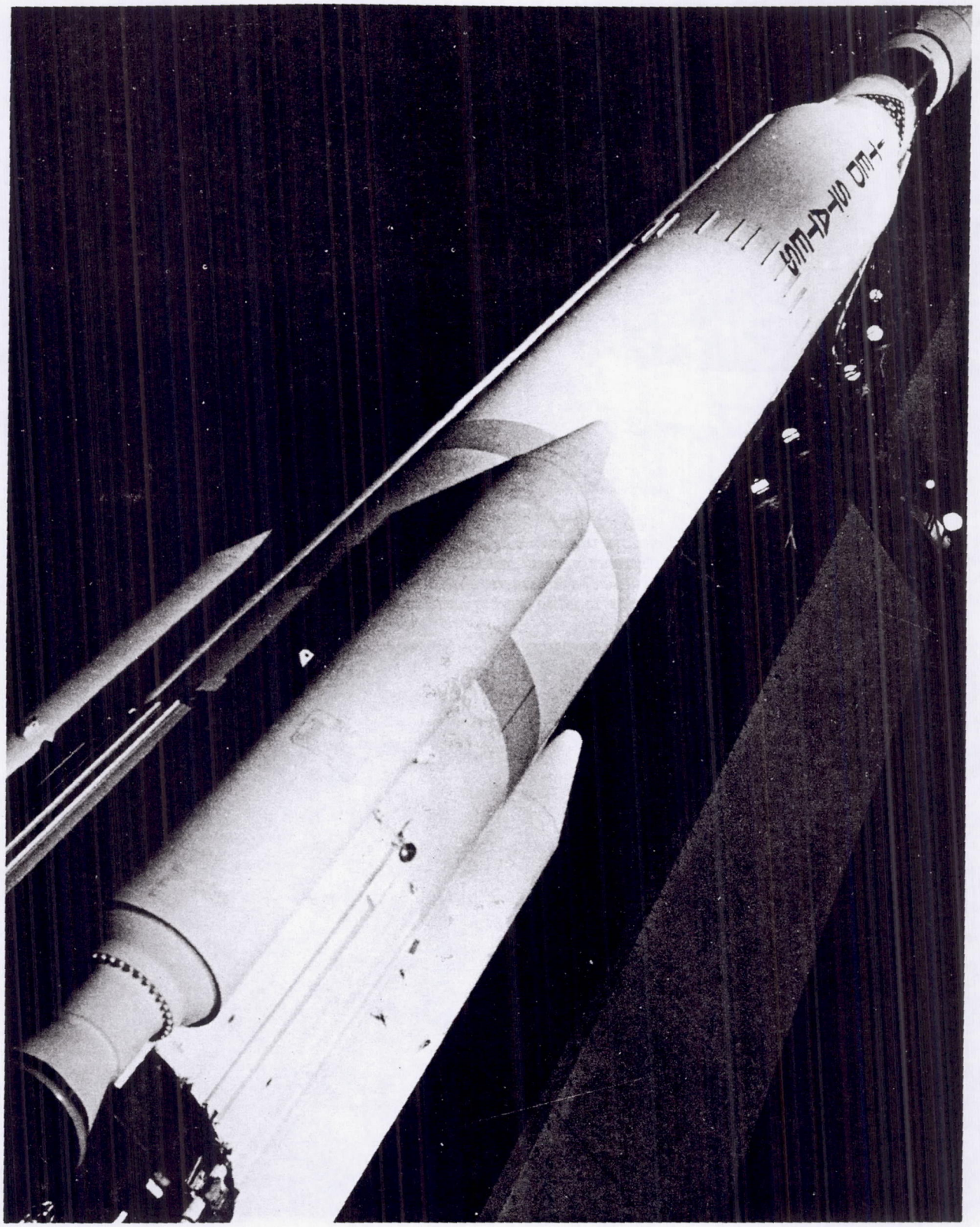
Project Results – Both spacecraft were successfully launched from the Western Test Range, Vandenberg AFB, California, Oct. 15, 1972. ITOS-D was placed in a near-polar, sun-synchronous orbit 909.5 by 907 miles. Inclination was 101.8 degrees; period was 115.1 minutes. AMSAT-OSCAR-6 was placed in a nearly identical orbit.

Major Participants – NOAA 2: Spacecraft management, NASA Goddard Space Flight Center for the National Oceanic and Atmospheric Administration. Spacecraft prime contractor, RCA. OSCAR 6 spacecraft management and construction, Radio Amateur Satellite Corp. (AMSAT). Launch vehicle management, Goddard Space Flight Center. Prime contractor, McDonnell Douglas Astronautics Co. Launch operations, Kennedy Space Center and KSC Unmanned Launch Operations at WTR.

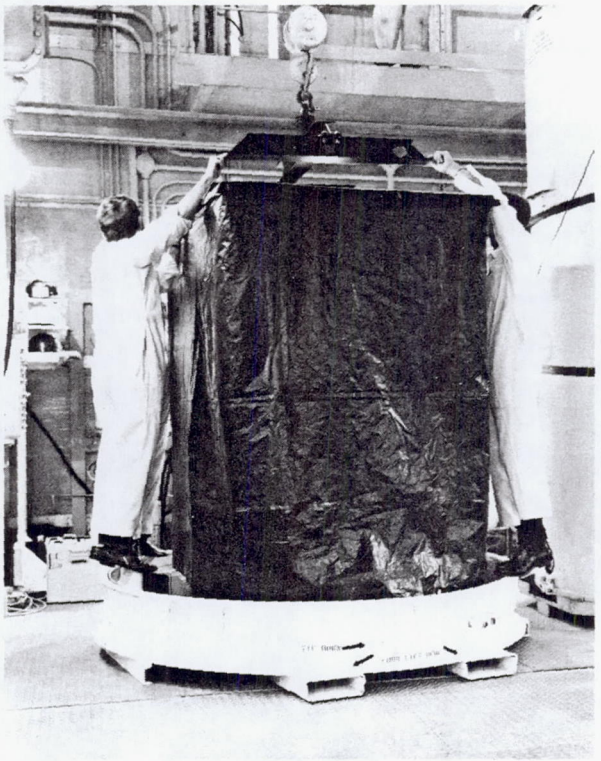
Key Spacecraft Personnel		Affiliation
ITOS-D (NOAA-2)		
PM	S. Weiland	NASA-GSFC
PS	I. L. Goldberg	NASA-GSFC
CO	C. M. Hunter	NASA-GSFC
SC	M. Tepper	NASA-GSFC
AMSAT-OSCAR-6		
PM	Unknown	Unknown
PS	Unknown	Unknown
CO	P. I. Klein	Amsat Corporation

Experiment	Experiment Personnel		Affiliation
ITOS-D (NOAA-2)			
Solar Proton Monitor	PI	D. J. Williams	NOAA-ERL
Scanning Radiometer (SR)	PI	Ness Staff	NOAA-NESS
Very High Resolution Radiometer (VHRR)	PI	Ness Staff	NOAA-NESS
Vertical Temperature Profile Radiometer	PI	Ness Staff	NOAA-NESS
	CO	S. Weiland	NASA-GSFC
AMSAT – OSCAR-6			
Telemetry + Tracking Beacons	CO	P. I. Klein	Amsat Corporation
Communications Repeater + Storage	CO	P. I. Klein	Amsat Corporation

ITOS-D/NOAA-2, a second generation operational meteorological satellite, is checked out prior to launch on October 15, 1972.

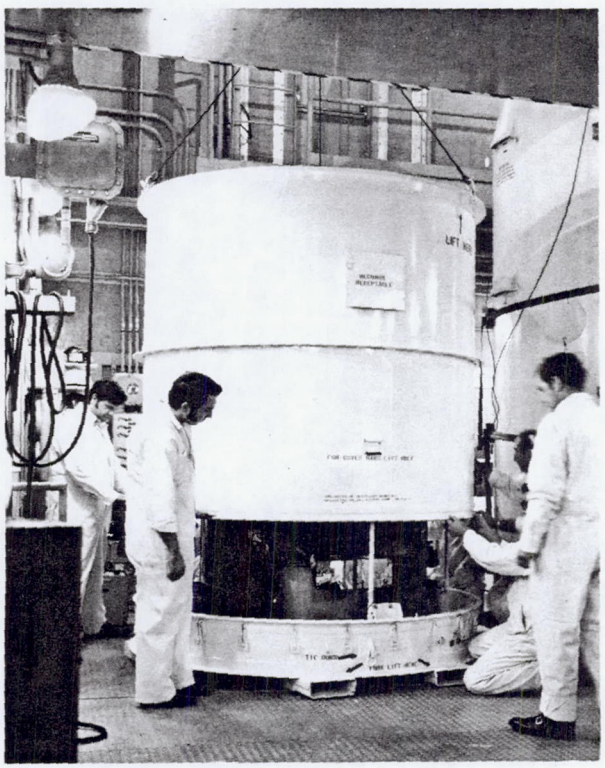


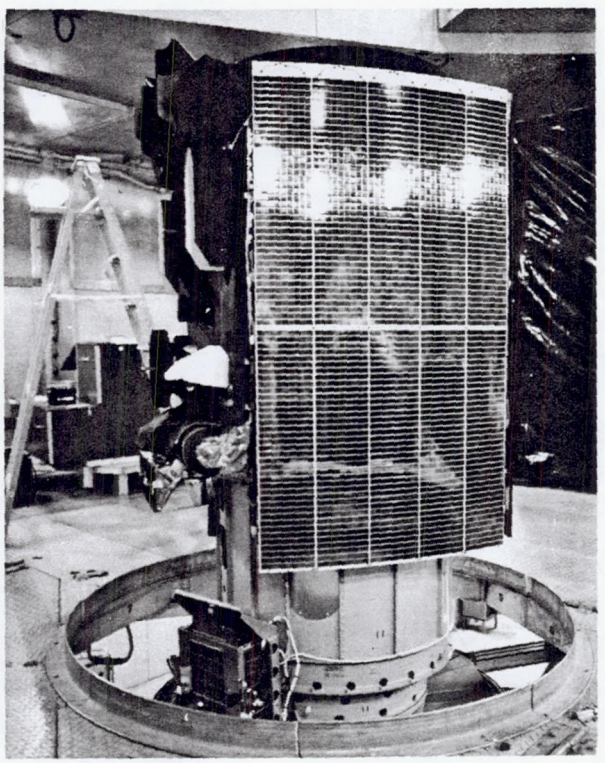
1972





Many hands and close teamwork assure space mission success. This series of photos shows assembly, test, and launch of ITOS-D/NOAA-2 operational weather satellite. The Delta launch vehicle also carried a small piggyback communications relay satellite serving radio amateurs.





ANIK I (Telesat-A)

Launch Vehicle – Delta 1914. First Delta "straight eight" with 8-foot shroud to enlarge second stage and 8-foot payload fairing. 480,000 pound thrust first stage with nine solid strap-ons; 9,800 pound second stage; TE 364-4 third stage with 15,000 pounds thrust. Inertially guided. Height: 115 feet.

Spacecraft Description – A cylinder 75 inches in diameter and 11.6 feet tall. Weight at launch, 1,238 pounds; weight in orbit, 650 pounds. Spacecraft was spin-stabilized with despun antenna and feeds. Control system was redundant hydrazine thrusters with seven-year station-keeping capability. Power system used solar panels and batteries with 250 watt minimum, including full 46-day eclipse capability.

Project Objectives – To provide commercial communications via satellite for Canada, which sprawls across nearly 4 million square miles.

Anik I was the first spacecraft of a geosynchronous system owned jointly by the Canadian government and Canadian telecommunications common carriers. Two spacecraft were to form the operational system; a third was to be held for possible in-flight failure or to extend the system. Anik, the Eskimo word for brother, was the world's first domestic communications satellite system using geosynchronous orbit.

Spacecraft Payload – Twelve high-capacity microwave channels, each to carry one color television picture or 960 one-way telephone conversations. Uplink was in the 5.925-6.425 GHz band; downlink was in 3.7-4.2 GHz band. Main antenna was a 60-inch parabola. Three-horn feed assembly accommodated receive and transmit frequencies.

Project Results – Anik I was launched November 9, 1972 from Kennedy Space Center aboard a three-stage Delta 1914 launch vehicle into an initial highly elliptical orbit which was circularized November 13. It was gradually moved on station at 114 degrees west longitude by year end.

Major Participants – Telesat Canada, owner; spacecraft prime contractor, Hughes Aircraft Co.; major subcontractors, Spar Aerospace Products, Ltd., and Northern Electric Co., Ltd., both of Canada; launch vehicle prime contractor, McDonnell Douglas Astronautics Co.; Launch services, NASA Kennedy Space Center under contract with Telesat.

ESRO-IV

Launch Vehicle – Scout.

Spacecraft Description – Cylindrical spacecraft 35 inches high and 29.25 inches in diameter, weighing 253 pounds including 70.4 pounds of scientific payload. Three equally spaced booms carrying instruments deployed outwards in orbit.

Project Objectives – Investigation of the ionosphere, the near magnetosphere, and auroral and solar particles.

Spacecraft Payload – Five scientific experiments: investigation of ionic species; neutral gas measurement; low energy particle investigation; polar cap absorption of high energy solar particles; flux and energy measurement of various particles; and the Horizon Crossing Indicator, a technological experiment to qualify the IR horizon sensor.

Project Results – ESRO IV was launched November 21, 1972, from the Western Test Range into a near polar 726.6 by 152.8 mile orbit. Experiments were activated and operated normally in the first month of the spacecraft's planned 18-month operational lifetime.

Major Participants – Program management; European Space Research Organization (ESRO); Prime Spacecraft contractor, Hawker Siddeley Dynamics, United Kingdom; Solar cells, AEG-Telefunken, West Germany; Experiments, Mullard Space Science Laboratory of University College, London; University of Bonn; Kiruna Geophysical Observatory, Sweden; Sterrekundig Institute, the Netherlands; Max Planck Institute, Garching; Horizon Crossing Indicator, European Space Research and Technology Centre, the Netherlands. Launch operations, NASA. Launch Vehicle prime contractor, LTV Aerospace.

APOLLO XVII

Launch Vehicle – Saturn V (SA-512). Similar to Apollo XVI vehicle. S-IC first stage produced about 7,665,111 pounds of thrust at liftoff. S-II second stage produced 1,153,712 pounds of thrust, and S-IVB third stage produced 208,242 pounds of thrust. Total weight of the Apollo XVII stack at ignition was 1,234,567 pounds.

Spacecraft Description – Third of the "J" series of spacecraft; similiar to Apollo 16. Scientific Instrument Module (SIM) again included in the service module, but experiments significantly changed. Total spacecraft weight at launch was 116,269 pounds: command module "America" 66,844 pounds; lunar module "Challenger" 36,262 pounds; spacecraft-LM adapter (SLA) 4,059 pounds; launch escape system 9,104 pounds.

Project Objectives – Primary objectives were (1) investigate the lunar surface and its environment at a selected landing site in the Taurus-Littrow region; (2) emplace and activate surface experiments; (3) perform experiments in lunar orbit; (4) obtain and return lunar surface samples; and (5) enhance the capability for future manned lunar exploration. The landing site was in a dark deposit between massif units on the southeastern rim of Mare Serenitatis. It was selected because the region is geologically complex and offers variety in age, albedo, composition, and origin of surface samples. The Apollo lunar surface experiments package was the fifth to become operational. Orbit science experiments again were concentrated in the SIM bay.

Spacecraft Payload – Substantially changed from other "J" missions in the types of scientific experiments carried. The fifth ALSEP station included another heat flow experiment with associated percussive drill; lunar ejecta and meteorites experiment (LEAM) to measure the physical parameters of primary cosmic dust particle impacts on sensors in cislunar space and of lunar ejecta from impacts on the moon's surface; lunar seismic profiling experiment (LSP), to determine physical properties of materials near the lunar surface and to monitor seismic waves from moonquakes or impacts; lunar atmospheric composition experiment (LACE), to investigate and monitor changes in the lunar ambient atmosphere; lunar surface gravimeter, to measure gravity acceleration and any variations at a specific point on the lunar surface. Experiments independent of ALSEP were geology investigation, a traverse gravimeter to measure local variations in gravity, soil mechanics experiment to determine physical properties, experiment to determine subsurface layering, search for subsurface water, and measure electrical properties of lunar materials in situ; and the lunar neutron probe experiment, to gather data on neutron capture rates and energy in the regolith. In addition, a long-term surface exposure experiment involved pre-flight photography of selected equipment and storage of equipment samples for comparison with Apollo XVII items that may be returned to earth after 1992. SIM bay experiments were: the lunar sounder to investigate the lunar subsurface to a depth of 1.3 kilometers; the infrared scanning radiometer to provide a lunar surface temperature map; the far ultraviolet

spectrometer to measure some constituents of the lunar atmosphere, plus solar and galactic UV; the gamma ray spectrometer identical to Apollos XV and XVI; and the panoramic camera, mapping camera, and laser altimeter. Lunar module payload again included a lunar roving vehicle. Crew for Apollo XVII included spacecraft Commander Eugene A. Cernan, a Navy captain making his third spaceflight; Command Module Pilot Ronald E. Evans, a Navy commander; and lunar module pilot Harrison H. (Jack) Schmitt, a civilian geologist. It was the first spaceflight for both Evans and Schmitt, and Schmitt was the first scientist to land on the moon.

Project Results – Apollo XVII lifted off at 12:33 a.m. EST, December 7, 1972 from Launch Complex 39 at Kennedy Space Center, Florida, after a two-hour, 40-minute delay caused by a malfunction in the countdown sequencer. No significant problems affected spacecraft operation during the mission. Lunar module "Challenger" landed at Taurus-Littrow slightly North of planned touchdown point about 2:55 p.m. EST, December 11, 1972. First extravehicular activity (EVA) began four hours later. Astronauts unpacked equipment and lunar rover. "Eyelid" was accidently torn from Rover fender by Cernan, but was later replaced on site. ALSEP was deployed and activated with all experiments operating except LSG. Astronauts drove South on abbreviated geology traverse to Steno Crater where rake/soil samples and chips from a small boulder were collected. Return included a stop near the LM to deploy SEP antenna array. Three explosive charges for LSP also were deployed during the traverse. Second EVA began at 6:17 p.m. EST, December 12 and set Apollo records for both time and distance. Astronauts drove west, then southwest, crossing dark mantle material with light mantle incursions, finally topping a massive landslide of light material to reach Nansen Crater at the base of South Massif. Area was thoroughly photographed and sampled. At second stop, near Lara Crater, trenching uncovered subsurface marbling of light and medium gray materials. Major find of the mission came at the third stop, Shorty Crater. Schmitt found orange soil on crater's rim, to be studied after age-dating eliminated hypothesis that it came from recent volcanic activity. Final stop at Camelot Crater provided samples verifying the differences between material from South Massif and from valley floor. Additional LSP charges (3) were deployed during traverse. The last lunar surface EVA of the Apollo program began at 5:23 p.m. EST, December 13, 1972. Traverse was north to sample boulders and material at the base of North Massif, then east and southeast to the Sculptured Hills. Final stop of the modified traverse plan was Van Serg Crater, a fresh crater that proved to be from an impact rather than volcanic. Lunar module lifted off at 5:55 p.m. the same day, completing a normal rendezvous and docking about two hours later. Challenger ascent state was jettisoned and deorbited on time, but impact was not seen on television because the trajectory placed the stage about 15 kilometers from the landing site, on the south side of South Massif. America spent an additional day in lunar orbit gathering data with the SIM bay instruments. Transearth injection came at 6:35 p.m. EST, December 16. Evans successfully performed a 67-minute cislunar EVA to retrieve film and data canisters from the SIM bay on December 17. Entry was normal

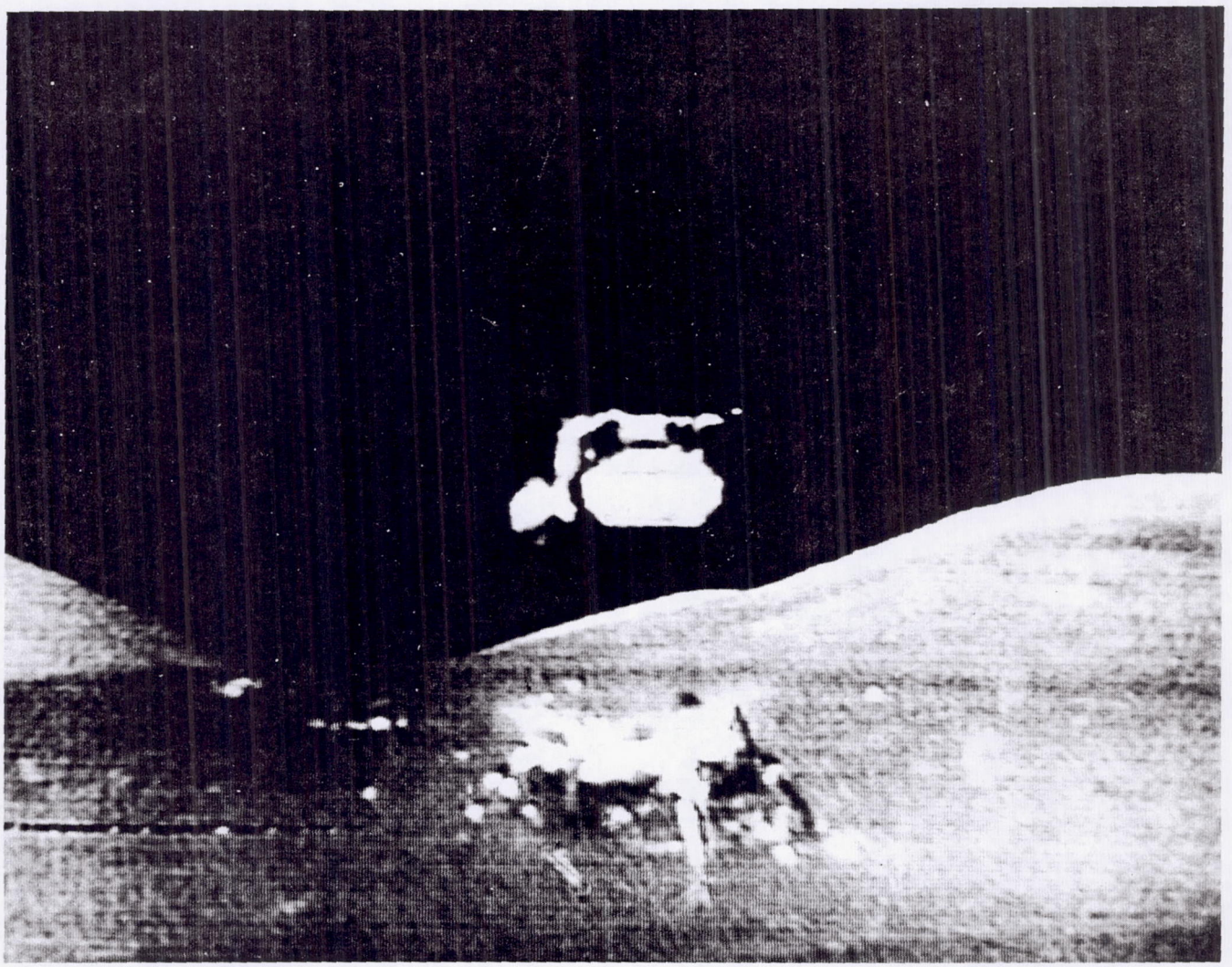
with Apollo XVII splashdown at 2:24 p.m. EST, December 19, about 3.9 miles from the recovery carrier. Apollo XVII established a number of records: longest stay on the lunar surface, 74 hours, 59 minutes, 38 seconds; longest single EVA in time and distance, 7 hours, 37 minutes, 21 seconds and 11.8 miles; longest total lunar surface EVA time, 22 hours, five minutes, six seconds; longest total distance traversed with Rover, 21 miles; longest Apollo mission, 301 hours, 51 minutes; longest time in lunar orbit, 147 hours, 48 minutes; most samples returned to Earth, 250 pounds.

Major Participants – Program management: NASA Office of Manned Space Flight. Spacecraft management: NASA Manned Spacecraft Center. CM and SM spacecraft prime contractor: Rockwell International. Principal contractors: SPS, Aerojet-General; ablative heat shield, AVCO; communication and data subsystems, Collins; environmental control system, Garrett. LM spacecraft prime contractor; Grumman. Principal contractors; Primary guidance and navigation system. General Motors (manufacturing) and MIT (technical management) ascent engine, Rockwell International; communications subsystems and radar and control electronics, RCA; descent engine and abort guidance system, TRW. Astronauts' portable life support systems: Hamilton-Standard. Space suits: ILC Industries. Apollo Lunar Surface Experiments Package: Bendix IU prime contractor: IBM. Apollo-Saturn V technical integration and evaluation: Boeing. Apollo checkout equipment, related engineering and design, quality management, and engineering support: GE. Mission trajectory control and spacecraft system analysis: TRW. Launch vehicle management: NASA Marshall Space Flight Center. First stage prime contractor: Boeing. Second stage: Rockwell International. Third stage: McDonnell Douglas. Launch operations: NASA Kennedy Space Center. Manned Space Flight Network management: Goddard Space Flight Center. Lunar Rover Vehicle prime contractor: Boeing; major subcontractor: Delco Electronics Division of General Motors. P&F Subsatellite management: NASA MSC; prime contractor; TRW. SIM bay management: NASA MSC; integrator; Rockwell International.

Key Spacecraft Personnel	Affiliation
CMS, Apollo XVIIA	
PM R. Petrone	NASA Headquarters
LM Alsep, Apollo XVIIC	
PM W. F. Eichelman	NASA-JSC
MG F. I. Roberson	NASA Headquarters
SC J. B. Hanley	NASA Headquarters
PS None Assigned	

Experiment	Experiment Personnel		Affiliation
S-Band Transponder	PI	W. L. Sjogren	NASA-JPL
Faraday Ultraviolet Spectrometer	PI	W. G. Fastie	Johns Hopkins University
Iridium Radiometer	PI	F. J. Low	University of Arizona
Lunar Sounder	PI	R. Phillips	NASA-JPL
Handheld Photography	PI	F. J. Doyle	U.S. Geological Survey
Panoramic Photography	PI	F. J. Doyle	U.S. Geological Survey
Metric Photography	PI	F. J. Doyle	U.S. Geological Survey
Stellar Photography	PI	F. J. Doyle	U.S. Geological Survey
Laser Altimeter	PI	W. M. Kaula	University of California, Los Angeles
Window Meteoroid	PI	B. G. Cour-Palais	NASA-JSC
	OI	M. L. Brown	Lockheed Electronics
	OI	D. S. McKay	NASA-JSC
Biostack	PI	H. Bucker	DFVLR
	OI	G. Horneck	University of Frankfurt
Heat Flow With Drill	PI	M. G. Langseth	Lamont-Doherty Geological Observatory
	OI	S. P. Clark, Jr.	Yale University
	OI	J. L. Chute, Jr.	Lehman College
Lunar Geology	PI	G. Swann	U.S. Geological Survey
Gravity Traverse	PI	M. Talwani	Lamont-Doherty Geological Observatory
Soil Mechanics	PI	J. K. Mitchell	University of California, Berkeley
Ejecta and Meteorites	PI	O. E. Berg	NASA-GSFC
Seismic Profiling	PI	R. I. Kovach	Stanford University
	OI	J. S. Watkins	University of Texas, Galveston
S/Electrical Property	PI	G. M. Simmons	Massachusetts Institute of Technology
Atmospheric Composition	PI	J. H. Hoffman	University of Texas, Dallas
Surface Gravimeter	PI	J. Weber	University of Maryland
	OI	J. V. Larson	University of Maryland
S.W. Comp. Deleted–JJB	PI	J. Geiss	University of Berne
Lunar Surface Cosmic Rays	PI	R. M. Walker	Washington University
	OI	P. B. Price	University of California, Berkeley
	OI	R. L. Fleischer	General Electric Company
	OI	E. Zinner	Washington University
	OI	M. Maurette	CNRS, Center for Spectrum

Experiment	Experiment Personnel	Affiliation
Neutron Probe	PI D. S. Burnett	California Institute of Technology
S-Band Transponder	PI W. L. Sjogren	NASA-JPL



Apollo XVII lunar module "Challenger" ascent stage leaves the Taurus-Littrow landing site in a liftoff from the lunar surface. This picture was obtained from a television transmission made by camera mounted on the lunar roving vehicle, remotely controlled from the mission control center in Houston, Texas. The liftoff occurred at 4:54:36 pm, CST, on December 14, 1972 completing manned lunar explorations under NASA's Apollo program.

NIMBUS E

Launch Vehicle – Delta 900. Same as ERTS launch vehicle.

Spacecraft Description – Butterfly-shaped spacecraft with 5-foot diameter ring lower section housing experiments and supporting equipment. A hexagonal upper section contains the attitude control system. Two solar panels provide more than 200 watts of power. Overall height was 10 feet; width 11 feet. The three-axis stabilized spacecraft weighed 1,580 pounds.

Project Objectives – Nimbus served as a testbed in NASA's meteorological program for research and development of new sensors, subsystems and system configurations. Improved systems and technology for weathercasting growing out of Nimbus flights were used in operational metsats such as the ITOS series. Nimbus E was a continuation of development of new meteorological sensors, subsystems and system configurations; study spatial and temporal distribution of the atmospheric structure, especially temperature, ozone, and water vapor; provide a data base for long-range global weather forecasting.

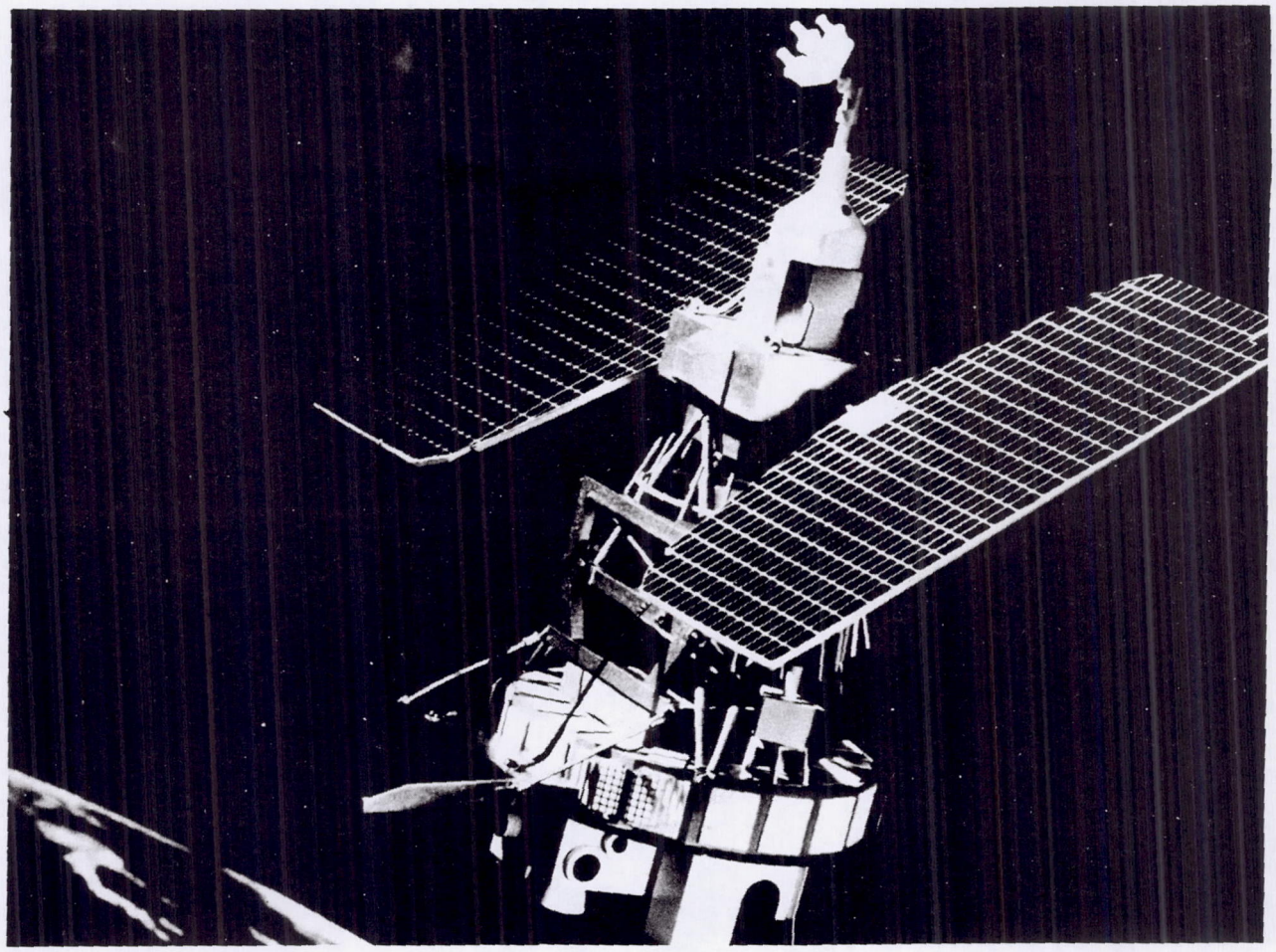
Spacecraft Payload – Four new instruments: electrically scanning microwave radiometer, infrared temperature profile radiometer, Nimbus-E microwave spectrometer, and surface composition mapping radiometer; and improved versions of two instruments flown on earlier missions: selective chopper radiometer and temperature humidity infrared radiometer. Payload weight was approximately 490 pounds.

Project Results – Launched from Western Test Range on December 11, 1972 into a 1,101 by 1,104-km polar orbit.

Major Participants – Project management: NASA-Goddard; Structure, supporting systems, and spacecraft integration and test: General Electric; Experiments: NASA-Goddard (3), NOAA, MIT/JPL, and Heriot Watts University/Oxford University; Launch vehicle: McDonnell Douglas.

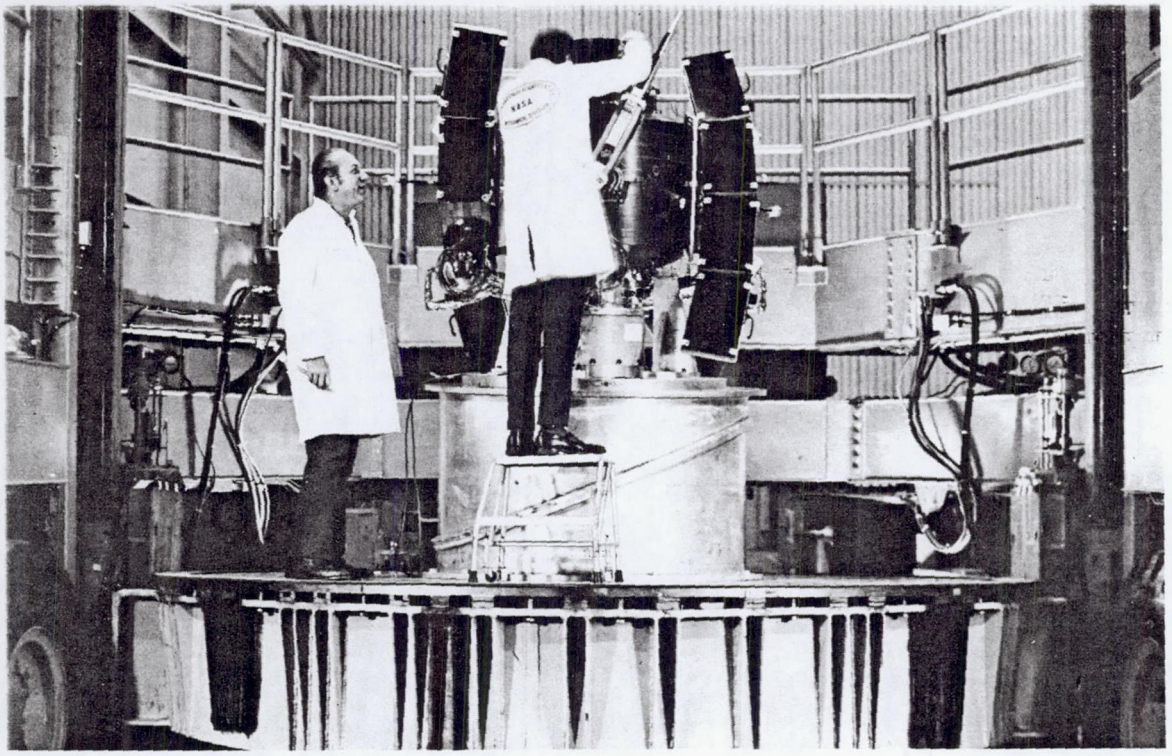
Key Spacecraft Personnel		Affiliation
PM	C. M. Mackenzie	NASA-GSFC
CO	G. J. Delio	NASA-GSFC
PS	M. Tepper	NASA-GSFC
SC	R. J. Arnold	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Iridium Temperature Profile Radiation	PI	W. I. Smith	NOAA-NESS
	OI	D. Q. Wark	NOAA-NESS
Selective Chopper Radiation	PI	J. T. Houghton	Oxford University
	OI	S. D. Smith	Reading University

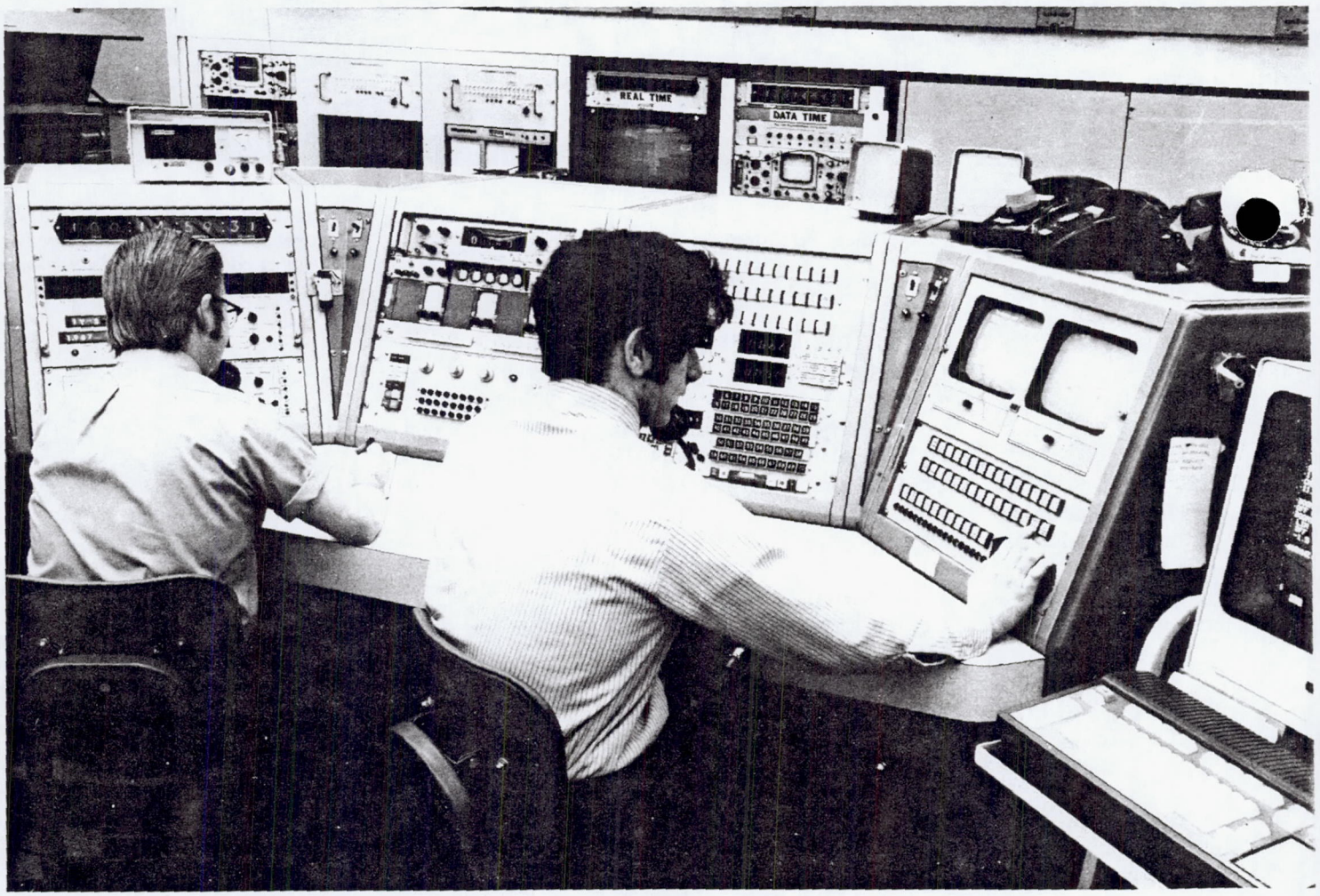


The Nimbus-E was a stabilized, Earth-oriented platform for testing advanced systems collecting meteorological and geological data.

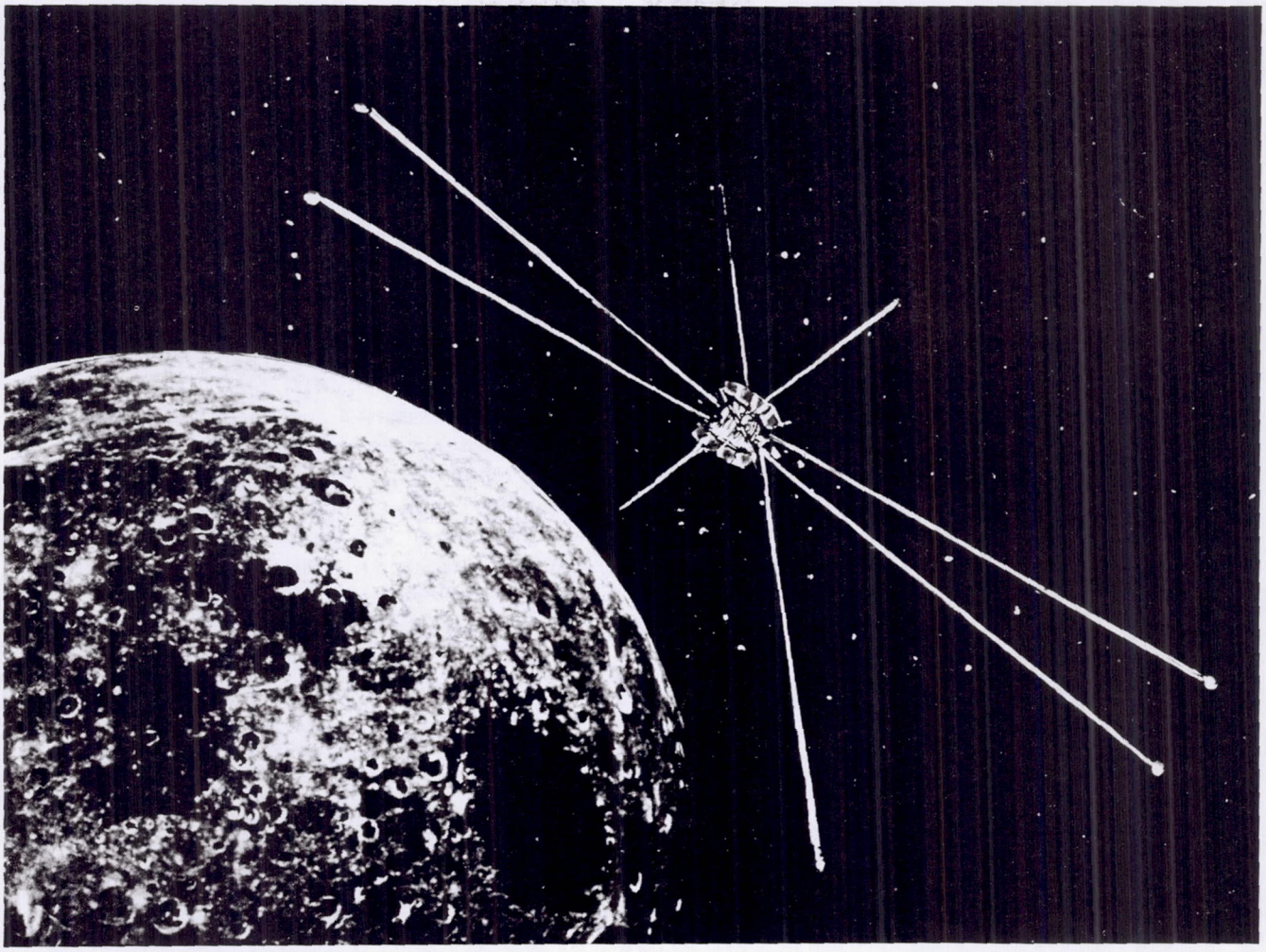
Experiment	Experiment Personnel		Affiliation
Microwave Spectrometer	PI	D. H. Staelin	Massachusetts Institute of Technology
	OI	F. T. Barath	NASA-JPL
	OI	N. E. Gaut	Environmental Research and Technology, Incorporated
	OI	P. Thaddeus	NASA-GISS
	OI	W. B. Lenoir	NASA-JSC
Electronic Scanner Microwave Radiation	PI	T. T. Wilheit, Jr.	NASA-GSFC
	OI	P. Gloersen	NASA-GSFC
SFC Comp. Mapping Radiation	PI	W. A. Hovis	NOAA-NESS
	OI	W. Callahan	Fairfield University
Int. Sc. Inv-Not Flown	PI	Unknown	Unknown
Tracking Data Relay Cancelled	PI	R. H. Pickard	NASA-GSFC
	PS	F. O. Vonbun	NASA-GSFC
	OI	P. J. Heffernan	NASA-GSFC
	OI	P. E. Schmid, Jr.	NASA-GSFC
Temperature-Humidity Iridium Radiation	PI	A. W. McCulloch	NASA-GSFC

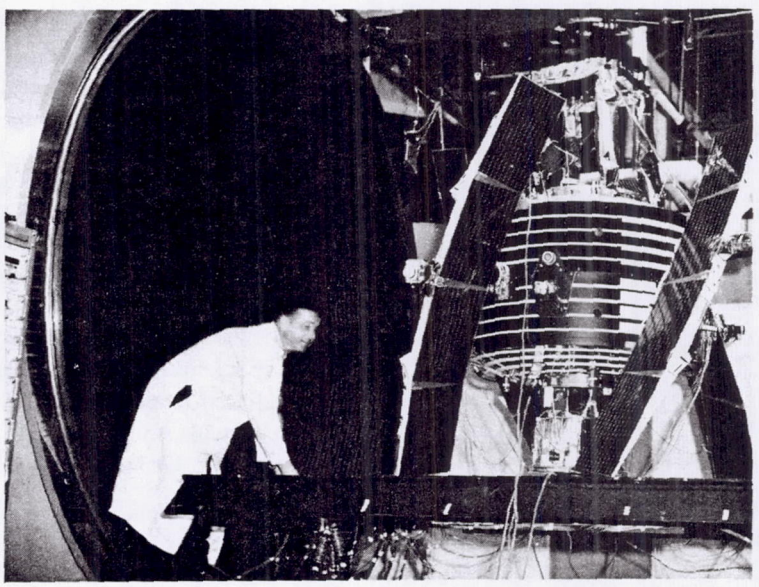


(Below) Manning the Radio Astronomy Explorer-B (RAE-B) console where signals were received investigating low-frequency signals from galactic and extra-galactic radio sources and from the Sun, Earth, and Jupiter. Extraneous noise obscures these signals on the ground.



1973





RAE-B was launched on June 10, 1973. Artist's sketch of RAE-B in orbit around the Moon (top) and testing of the satellite at Goddard Space Flight Center (right and upper left).

PIONEER G (11)

Launch Vehicle – Three-stage Atlas-Centaur-TE-M-364-4.

Spacecraft Description – The spacecraft equipment compartment was a 14-inch-deep flat box, top and bottom of which were regular hexagons 28 inches on a side. One side joined to a smaller box also 14 inches deep whose top and bottom were irregular hexagons. The smaller box contained 37 pounds of onboard experiments. Attached to the hexagonal front face of the equipment compartment was a 9-foot-diameter, 18-inch-deep antenna. High-gain antenna feed and medium-gain antenna horn were mounted at the focal point of the antenna dish on three struts projecting about four feet forward of the rim of the dish. The low-gain antenna extended about 2.5 feet behind the equipment compartment. Two three-rod trusses, 120 degrees apart, projected from two sides of the equipment compartment to deploy the radioisotope thermoelectric generator (RTG) power sources about 10 feet from the center of the spacecraft. A third boom, 120 degrees from each of the other two, projected from the experiment compartment and positions the magnetometer sensor 21.5 feet from the spacecraft center. At the rim of the antenna dish was a sun sensor. A star sensor looked through an opening in the equipment compartment and was protected from sunlight by a hood. Both compartments had aluminum frames with bottoms and side walls of aluminum honeycomb. The dish antenna was made of aluminum honeycomb sandwich. Rigid external tubular trusswork supported the dish antenna, three pairs of thrusters located near the rim of the dish, boom mounts, and launch vehicle attachment ring. The spacecraft was spin-stabilized at 4.8 rpm. Total weight of Pioneer 11 at launch was 570 pounds, including 66 pounds of scientific instruments. RTGs provided 120 watts of power to the spacecraft and its experiments.

Project Objectives – To investigate the interplanetary medium beyond the orbit of Mars, the Asteroid Belt, and the near-Jupiter environment.

Spacecraft Payload – Twelve instruments and the spacecraft radio, which was used to conduct two experiments (celestial mechanics and S-band occultation). The instruments included a meteoroid detector, an asteroid/meteoroid detector, a plasma analyzer, a vector helium magnetometer, a charged-particle detector, a cosmic-ray telescope, a geiger-tube telescope, a trapped-radiation detector, ultraviolet photometer, infrared radiometer, an imaging photopolarimeter and a flux-gate magnetometer.

Project Results – Pioneer G was successfully launched April 6, 1973, from Kennedy Space Center, Fla. It crossed the moon's orbit 11 hours after launch. It entered the asteroid belt Aug. 18, 1973, and was expected to emerge March 18, 1974. Jupiter encounter was expected Dec. 5, 1974.

Major Participants – Pioneer-Jupiter program was directed by the Office of Space Science, NASA Headquarters; project management, NASA Ames Research Center; spacecraft prime contractor, TRW Systems group; launch vehicle management, NASA Lewis Research Center; launch vehicle prime contractors, General Dynamics/Convair (Atlas-Centaur) and Thiokol, Inc.

Key Spacecraft Personnel		Affiliation
PM	C. F. Hall	NASA-ARC
PS	J. H. Wolfe	NASA-ARC
MG	F. D. Kochendorfer	NASA Headquarters
SC	A. G. Opp	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
3 Axis Helium Magnetometer	PI	E. J. Smith	NASA-JPL
	OI	D. S. Colburn	NASA-ARC
	OI	P. Dyal	NASA-ARC
	OI	C. P. Sonett	University of Arizona
	OI	P. J. Coleman, Jr.	University of California, Los Angeles
	OI	L. Davis, Jr.	California Institute of Technology
	OI	D. E. Jones	Brigham Young University
Charged Particle Composition	PI	J. A. Simpson	University of Chicago
	OI	J. J. O'Gallagher	University of Maryland
	OI	A. Tuzzolino	University of Chicago
Asteroid Astronomy	PI	R. K. Soberman	General Electric Company
	OI	H. A. Zook	NASA-JSC
Meteoroid Detector	PI	W. H. Kinard	NASA-LARC
	OI	J. M. Alvarez	NASA-LARC
	OI	D. H. Humes	NASA-LARC
Jovian Trapped Particles	PI	R. W. Fillius	University of California, San Diego
	OI	C. E. McIlwain	University of California, San Diego
Ultraviolet Photometer, 200-800A	PI	D. L. Judge	University of Southern California
	OI	R. W. Carlson	University of Southern California
Image Photopolarimeter	PI	T. Gehrels	University of Arizona
	OI	D. L. Coffeen	NASA-GISS
	OI	J. Hameen-Anttila	University of Arizona
	OI	C. E. Kenknight	University of Arizona
	OI	R. F. Hummer	Santa Barbara Research Center
	OI	M. G. Tomasko	University of Arizona
	OI	W. Swindell	University of Arizona
Infrared Radiometer	PI	A. P. Ingersoll	California Institute of Technology
	OI	R. W. Boese	NASA-ARC
	OI	S. C. Chase, Jr.	Santa Barbara Research Center

Experiment	Experiment Personnel		Affiliation
	OI	G. Neugebauer	California Institute of Technology
	OI	L. M. Trafton	University of Texas, Austin
Celestial Mechanics	PI	J. D. Anderson	NASA-JPL
	OI	G. W. Null	NASA-JPL
S-Band Occultation	PI	A. J. Kliore	NASA-JPL
	OI	G. Fjeldbo	NASA-JPL
	OI	D. L. Cain	NASA-JPL
	OI	B. L. Seidel	NASA-JPL
	OI	S. I. Rasool	NASA Headquarters
Jovian Charged Particles	PI	J. A. Van Allen	University of Iowa
Charged Particle Telescope	PI	F. B. McDonald	NASA-GSFC
	OI	K. G. McCracken	CSIRO
	OI	W. R. Webber	University of New Hampshire
	OI	E. C. Roelof	Applied Physics Laboratory
	OI	B. J. Teegarden	NASA-GSFC
	OI	J. H. Trainor	NASA-GSFC
2 Quad'sphere Analyzers	PI	J. H. Wolfe	NASA-ARC
	OI	L. A. Frank	University of Iowa
	OI	R. Lust	MPI Headquarters
	OI	D. S. Intriligator	University of Southern California
	OI	V. T. Zavientseff	NASA-ARC
	OI	Z. A. Smith	NOAA-SEL
	OI	F. L. Scarf	TRW Systems Group
	OI	H. R. Collard	NASA-ARC
	OI	W. C. Feldman	Los Alamos Scientific Laboratory
	OI	D. D. McKibbin	NASA-ARC
Fluxgate Magnetometer	PI	M. H. Acuna	NASA-GSFC
	OI	N. F. Ness	NASA-GSFC
Zodiacal Light Photometer	PI	J. L. Weinberg	Space Astronomy Laboratory
	OI	M. S. Hanner	NASA-JPL
Imaging of Jupiter	PI	T. Gehrels	University of Arizona
	OI	D. L. Coffeen	NASA-GISS
	OI	J. Hameen-Anttila	University of Arizona
	OI	W. Swindell	University of Arizona
	OI	R. F. Hummer	Santa Barbara Research Center
	OI	C. E. Kenknight	University of Arizona
	OI	J. L. Weinberg	Space Astronomy Laboratory

ANIK 2
(Telesat B)

Launch Vehicle – Delta 1914.

Spacecraft Description – A cylinder 75 inches in diameter and 11.6 feet tall. Weight at launch: approximately 1,250 pounds; weight in orbit: about 630 pounds. Spacecraft was spin-stabilized with despun antenna and feeds. Control system was redundant hydrazine thrusters with seven-year station-keeping ability. Power was provided by solar panels with a 250-watt minimum; batteries provided 46-day eclipse capability.

Project Objectives – To provide commercial communications services for Canada, which sprawls across nearly 4 million square miles. Some circuits also were leased to U.S. carriers for private line voice, data and video communications between the east and west coasts and between both coasts and Alaska.

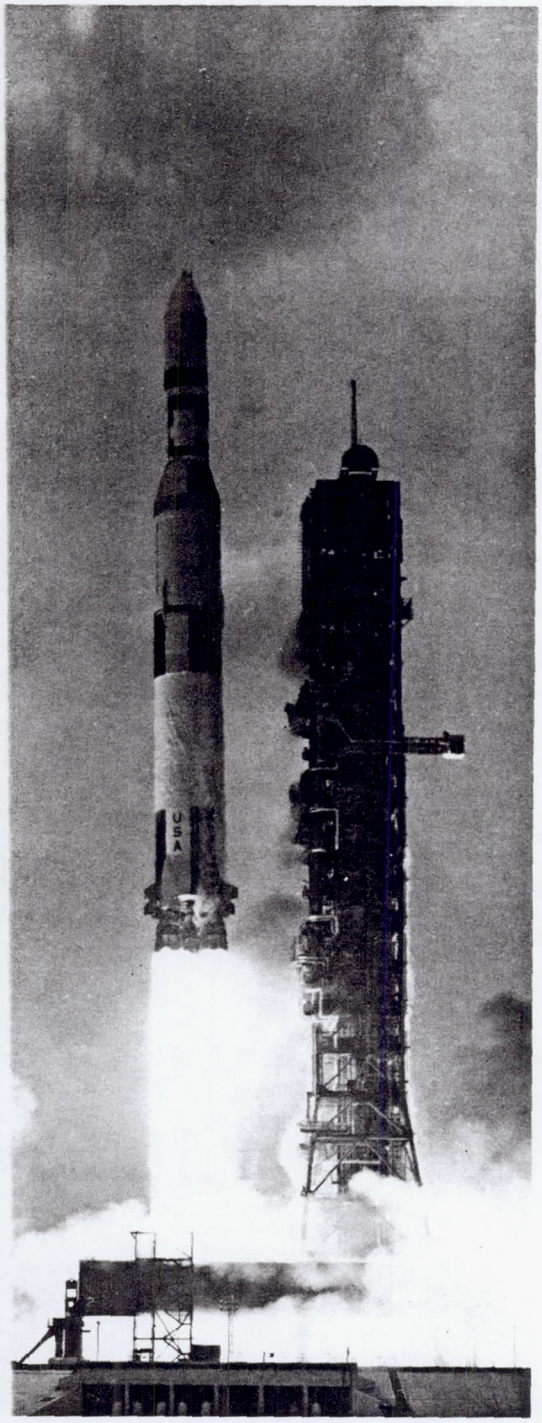
Spacecraft Payload – Twelve microwave channels, each carrying one color TV picture or 960 one-way telephone conversations. Uplink was in the 5.925 GHz band; downlink was in the 3.7 - 4.2 GHz band. Main antenna was a 60-inch parabola. Three-horn feed assembly accommodated receive and transmit frequencies.

Project Results – Anik 2 was launched April 20, 1973, and placed in service May 17, 1973, at 109 degrees west longitude.

Major Participants – Telesat Canada, owner. Spacecraft prime contractor, Hughes Aircraft Co.; Major subcontractors, Spar Aerospace Products, Ltd., and Northern Electric, Ltd., both of Canada; Launch vehicle prime contractor, McDonnell Douglas Astronautics Co.; Reimbursable launch services, NASA Kennedy Space Center.

Key Spacecraft Personnel	Affiliation
PM R. J. Goss	NASA-GSFC

SKYLAB 1



Skylab 1 was launched into Earth orbit at 1:30 p.m. EDT on May 14, 1973, on a modified Saturn V rocket.

Launch Vehicle – Two-stage Saturn V.

Space Station Description – Skylab was a cluster of four units, three habitable, together comprising a large orbiting space station. Units were the Orbital Workshop (OWS), containing the primary crew quarters and work areas; the Airlock Module (AM), containing extra-vehicular activity port and the station's control and monitoring instrumentation; the Apollo Telescope Mount (ATM), a solar observatory; and the Multiple Docking Adapter (MDA), containing docking ports and controls and displays for both the ATM and earth resources instruments. Modules were launched in-line, with the ATM at the upper end. In orbit, the ATM deployed to a 90-degree angle from the cluster. The OWS was a converted S-IVB rocket stage, 21.6 feet in diameter and 48.1 feet long. Its large liquid hydrogen tank was divided laterally by aluminum grillwork to create a two-story laboratory. The forward, or upper, compartment and dome was equipped with equipment and food lockers, refrigerators and freezers, water tanks, some control and display units, two Scientific Airlocks (SAL), space suits, and other items. The aft, or lower, compartment, included a wardroom, waste management compartment, crew quarters, and experiment compartment. The stage's liquid oxygen tank was converted to a waste tank by installing a waste disposal airlock in the experiment compartment. A deployable meteoroid shield was mounted on the OWS outer hull, as were two large deployable solar array winds designed to supply the station, except ATM, with electricity. Habitable volume of the OWS was more than 10,000 cubic feet. The AM was 17.6 feet long and 10 feet in diameter. Its airlock and hatch allowed extravehicular activity without depressurizing the station. The AM also housed storage areas and a variety of equipment. Habitable volume of the AM was 622 cubic feet. The ATM was the first orbiting solar observatory controlled by men in space, with limited ground control provided during crew sleep periods and between missions. It was 13.3 feet long and deployed vertically to the Skylab cluster. The module had independent power from large paddle-wheel solar arrays and supporting battery system; a five-camera television system for onboard monitoring or relay to Earth of solar images; five principal experiments; and data storage on film for retrieval and replacement by extravehicular astronauts. ATM operations were remotely controlled from the MDA. The MDA was 17.3 feet long and 10 feet in diameter. It had a spacecraft docking port at its forward, or upper end and a backup or rescue port in the side hull. the MDA housed a control and display console for the ATM, a furnace and vacuum chamber for "materials processing" experiments, and controls for the Earth Resources Experiments Package (EREP). EREP instruments were mounted on the MDA outer hull, as were docking lights and targets. Habitable volume of the MDA was 1,140 cubic feet.

Project Objectives – To determine and evaluate the effects of long-duration space flight on men and hardware; to observe Earth from orbit using a variety of instruments and develop and evaluate useful applications of data from space-borne sensors; to conduct scientific investigation in space to increase knowledge of the Sun, astronomy and physics, biology, and other disciplines; and to provide baseline information for development of the next generation of space stations.

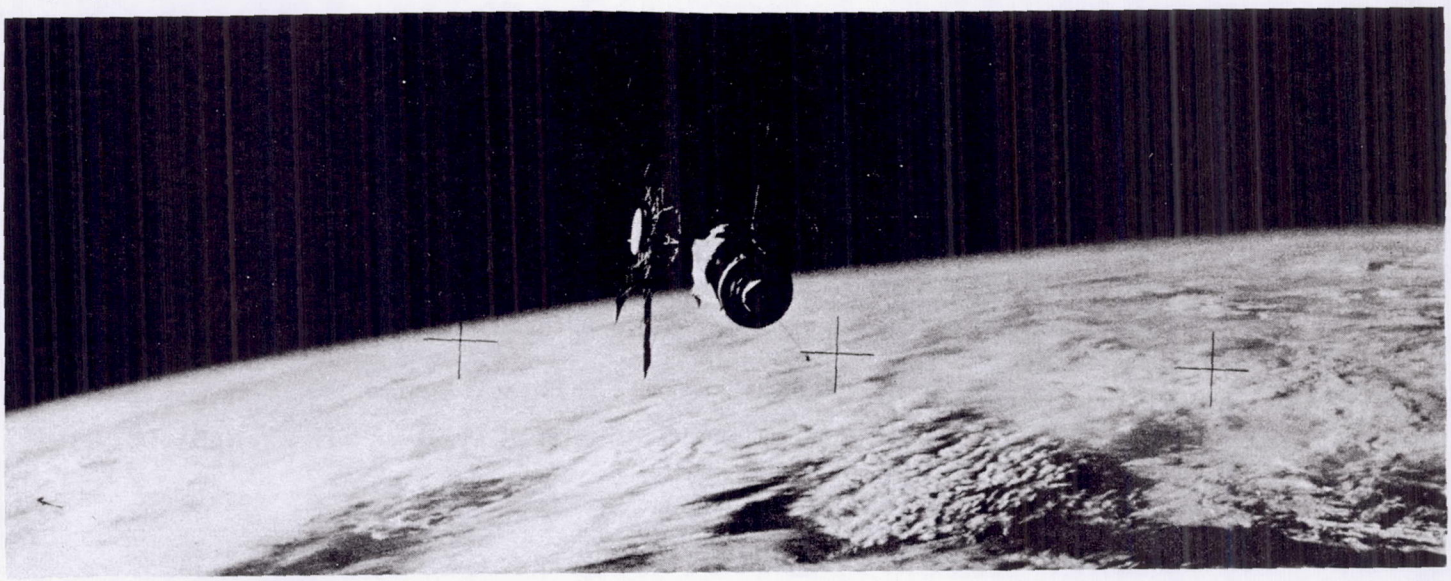
Note: Skylab was the first United States space station and the last major U.S. manned space program until a Space Shuttle became operational. With completion of Skylab, America entered a quiescent period for man-in-space exploration and exploitation – a dormancy to be broken only by the Apollo/Soyuz joint mission with the Soviet Union in 1975. Skylab began in 1973 and ended in 1974.

Space Station Payload – OWS: food, water, and clothing sufficient for three crews of astronauts on extended missions; equipment, film, and supplies for a variety of experiments in the fields of medicine, engineering and technology, and other sciences. AM: oxygen and nitrogen supplies, thermal and electrical power controls, atmosphere purification equipment, teleprinter, caution and warning instrumentation, and other equipment and storage. ATM: cameras, film, and instruments for five experiments including White Light Coronagraph, X-ray Spectrographic Telescope, Ultraviolet Scanning Polychromator-Spectroheliometer, Extreme Ultraviolet and X-ray Telescope, and a Coronal Extreme Ultraviolet Spectroheliograph and Chromospheric Extreme Ultraviolet Spectrograph. MDA: Controls and displays for the ATM and EREP, equipment and hardware for materials and space manufacturing experiments, externally mounted EREP instruments and cameras, including a Multrispectral Photographic Facility, Earth Terrain Camera, Infrared Spectrometer, Multispectral Scanner, Microwave Radiometer/Scatterometer and Altimeter, and L-Band Microwave Radiometer.



Project Results – Skylab 1 was launched from Kennedy Space Center on May 14, 1973. During launch a meteoroid/thermal shield tore loose from the OWS, ripping away one primary solar wing and jamming the other with debris. The ATM and its paddle-wheel solar array deployed as programmed in orbit, but the solar wing did not. Temperatures inside the station rose without thermal protection. Crew launch, scheduled for May 15, was delayed while the problems were analyzed. Solutions were carried out as integral parts of follow-on manned missions.

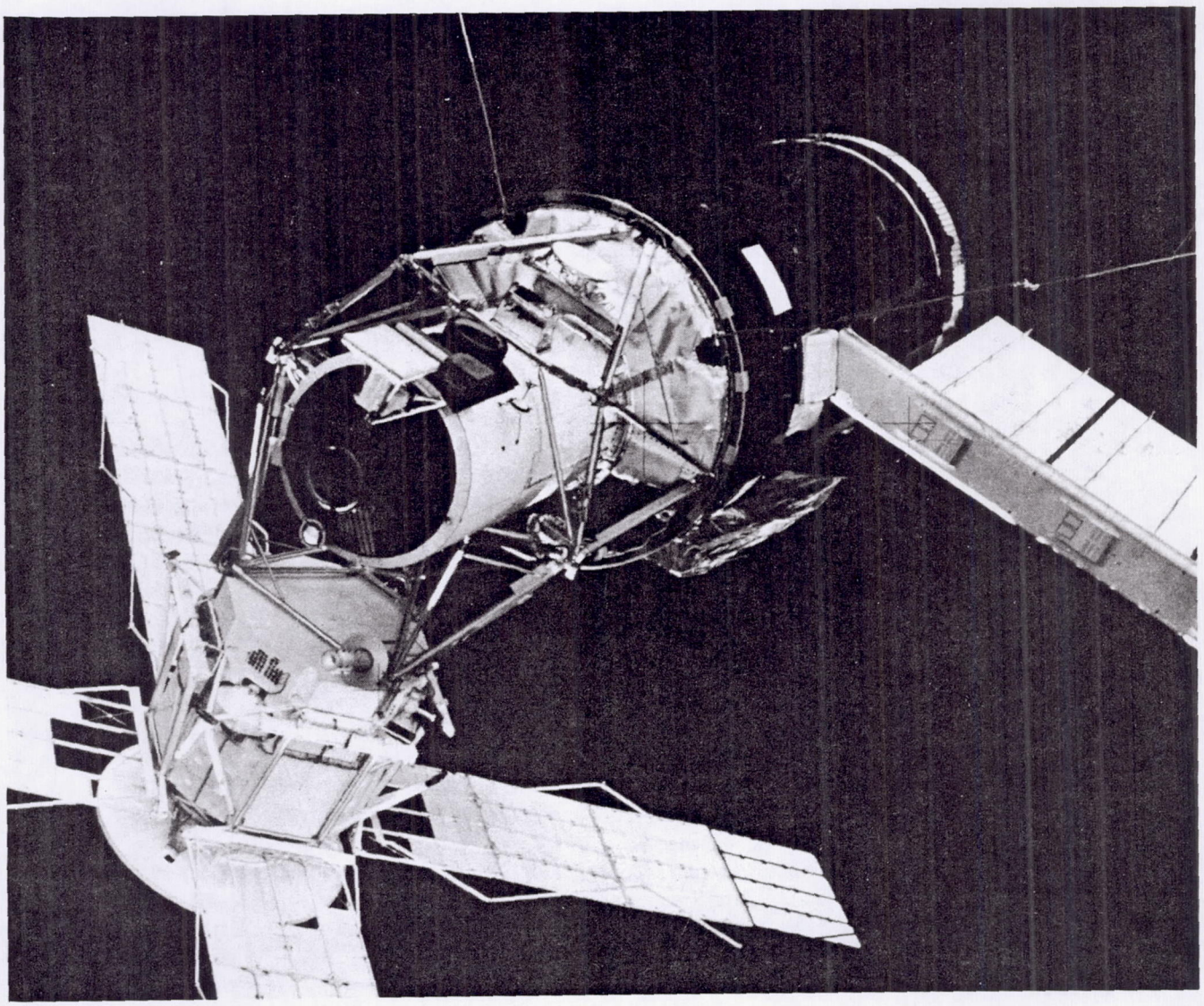
This view of Skylab 1 space stations was taken from Skylab 2 command service module manned by astronauts Charles Conrad, Jr., commander; Dr. Joseph P. Kerwin, science pilot; and Paul J. Weitz, pilot.



Key Spacecraft Personnel		Affiliation
PM O. G. Smith		NASA-JSC
Experiment	**Experiment Personnel**	**Affiliation**
Nuclear Emulsion	PI M. M. Shapiro	U.S. Naval Research Laboratory
Ultraviolet Stellar Astronomy	PI K. G. Henize	NASA-JSC
	OI J. D. Wray	University of Texas, Austin
X-Ray Ultraviolet Solar Photography	PI R. Tousey	U.S. Naval Research Laboratory
White Light Coronagraph	OI G. Newkirk, Jr.	High Altitude Observatory
	PI R. M. MacQueen	High Altitude Observatory
X-Ray Spectrometer Telescope	PI A. S. Krieger	AS+E, Incorporated
	OP G. S. Vaiana	AS+E, Incorporated
Ultraviolet Scan Polychromometer	PI R. W. Noyes	Harvard College Observatory
	OI E. M. Reeves	Harvard College Observatory
Dual X-Ray Telescope	PI J. H. Underwood	Aerospace Corporation
	OP E. Tandberg-Hanssen	NASA-MSFC
Ultraviolet Airglow Horizontal Photo	PI D. M. Packer	U.S. Naval Research Laboratory
Gegenschein/ Zodiacal Light	PI J. L. Weinberg	Space Astronomy Laboratory
EUV Corona S-Heliograph	PI R. Tousey	U.S. Naval Research Laboratory
	OI J. D. Purcell	U.S. Naval Research Laboratory
EUV Spectrograph	PI R. Tousey	U.S. Naval Research Laboratory
	OI J. D. Purcell	U.S. Naval Research Laboratory
Particle Collection	PI C. L. Hemenway	Dudley Observatory
Ultraviolet Panorama	PI G. Courtes	CNES
H Alpha Telescope 1 (Photo)	PI R. W. Noyes	Harvard College Observatory
	OI E. M. Reeves	Harvard College Observatory
H Alpha Telescope 2	PI None Assigned	None Assigned
M-Spectrometer Photography-EREP	PI K. Demel	NASA-JSC
1R Spectrometer-EREP	PI T. L. Barnett	NASA-JSC
10 Band Scanner-EREP	PI C. L. Korb	NASA-JSC

Experiment	Experiment Personnel	Affiliation
Microwave Scatt-EREP	PI D. E. Evans	Unknown
L-Band Radiometer EREP	PI D. E. Evans	Unknown
Expand Airlock Technology	PI R. B. Forbes	University of Alaska
	OI F. W. Forbes	USAF Aeropropulsion Laboratory
Thermal Coatings	PI W. L. Lehn	U.S. Air Force
Mineral Balance	PI C. D. Whedon	National Institutes of Health
	OI L. Lutwak	Cornell University
Bioassay Body Fluids	PI C. S. Leach	NASA-JSC

Skylab spacestation photographed from the Skylab 3 command module during the "fly around" inspection prior to docking. Aboard the command module were astronauts Alan L. Bean, Owen K. Garriot, and Jack R. Lousma, who remained with the Skylab space station in Earth orbit for 59 days.



1973

Experiment	Experiment Personnel		Affiliation
Specimen Mass Measurements	PI	J. W. Ord	USAF School of Aerospace Medicine
Vectorcardiogram	PI	N. W. Allebach	USN Aerospace Medical Research Laboratory
	OI	R. F. Smith	Vanderbilt University
Human Vestibular FN.	PI	A. Graybiel	USN Aerospace Medical Research Laboratory
	OI	E. Miller	USN Aerospace Medical Research Laboratory
Sleep Monitor	PI	J. D. Frost	Baylor University
Time and Motion Study	PI	J. F. Kubis	Fordham University
	OI	E. J. McLaughlin	NASA Headquarters
Metabolic Activity	PI	E. L. Michel	NASA-JSC
	OI	J. A. Rummel	NASA-JSC
Body Mass Measurements	PI	W. E. Thornton	NASA-JSC
Thermal Coatings	PI	E. C. McKannan	NASA-JSC
Zero-G Flam	PI	J. H. Kimzey	NASA-JSC
Habit. Crew Quarters	PI	C. C. Johnson, Jr.	NASA-JSC
Gravity Sub. Workbench	PI	J. B. Rendall	NASA-MSFC
EVA/IVA Hardware Evaluation	PI	J. T. Jackson	NASA-JSC
Astronaut Maneuvers Evaluation	PI	C. E. Whitsett, Jr.	U.S. Air Force
Materials	PI	R. M. Poorman	NASA-MSFC
	OI	J. R. Williams	NASA-MSFC
	OI	M. Rubinstein	Westinghouse Electric Corporation
	OI	E. A. Hasemeyer	NASA-MSFC
	OI	M. C. Davidson	NASA-MSFC
Manned Navigation Sight	PI	R. J. Randle	NASA-ARC
	OI	S. Powers	U.S. Air Force
Inflight Aerosol Analyzer	PI	W. Z. Leavitt	U.S. Department of Transportation
Crew Vehicle Disturbance	PI	B. A. Conway	NASA-LARC
Precision Apt. Track	PI	J. Gould	NASA-JSC
Foot Control Maneuvers	PI	D. E. Hewes	NASA-LARC
Coronagraph Contamination	PI	M. Greenberg	Dudley Observatory
	OI	G. P. Bonner	NASA-JSC
Contamination Measurements	PI	J. A. Muscari	Martin-Marietta Aerospace Corporation

Experiment	Experiment Personnel		Affiliation
Pilot Desc. Fn.	PI	F. G. Edwards	NASA-ARC
Skylab Experiment	PI	P. B. Price	University of California, Berkeley
Foil Ion Abundance	PI	J. Geiss	University of Berne
	OI	D. L. Lind	NASA-JSC
Bone Mineral Measurements	PI	J. M. Vogel	U.S. Public Health Service
	OI	J. R. Cameron	University of Wisconsin
Lower Body Negative Press	PI	R. L. Johnson	NASA-JSC
	OI	J. W. Ord	USAF School of Aerospace Medicine
Cytogenic Study Blood	PI	L. H. Lockhart	University of Texas, Galveston
	OI	P. C. Gooch	Unknown
Man's Immunity	PI	S. E. Ritzmann	University of Texas, Austin
	OI	W. C. Levin	University of Texas, Austin
Blood Volume, Red Cell	PI	P. C. Johnson	Baylor University
Red Blood Cell Metabolism	PI	C. E. Mengel	University of Missouri
Hematologic Effect	PI	S. L. Kimzey	NASA-JSC
	OI	C. L. Fischer	Eisenhower Hospital
Electric Furnace	OI	A. Deruytherre	Catholic University of Belgium
	OI	H. Walter	University of Alabama
	OI	T. Kawada	National Research Institute
	OI	A. O. Ukanwa	NASA-MSFC
	PI	H. Wiedemeier	Rensselaer Polytechnic
	OI	J. O. Reger	TRW Systems Group
	OI	W. R. Wilcox	University of Southern California
	OI	H. C. Gatos	Massachusetts Institute of Technology
	OI	A. F. Witt	Massachusetts Institute of Technology
	OI	F. A. Padavani	Texas Instruments Corporation
	OI	A. S. Yue	University of California, Los Angeles
	OI	E. A. Hasemeyer	NASA-MSFC

Experiment	Experiment Personnel		Affiliation
Crew Activity/ Maintenance	PI	R. L. Bond	NASA-JSC
Atmospheric Heat Absorption	PI	J. R. Zmolek	Lourdes High School
	OI	W. L. Behring	Lourdes High School
Volcano Study	PI	T. A. Crites	Kent Junior High School
	OI	R. C. Putnam	Kent Junior High School
Libration Clouds	PI	A. Hopfield	Princeton Day School
	OI	N. Sperling	Princeton Day School
Objects Within Mercury Orbit	PI	D. C. Bochsler	Silverton Union High School
	OI	J. P. Daily	Silverton Union High School
Ultraviolet From Quasars	PI	J. C. Hamilton	Aiea High School
	OI	J. A. Fuchigami	Aiea High School
X-Ray Stellar Classes	PI	J. W. Reihs	Tara High School
	OI	H. W. Boyd	Tara High School
Jovian X-Rays	PI	J. I. Leventhal	Berkeley High School
	OI	H. E. Choulett	Berkeley High School
Ultraviolet From Pulsars	PI	N. W. Shannon	Fernbank Scientific Center
	OI	P. H. Knappenberger	Fernbank Scientific Center
Bacteria and Spores	PI	R. L. Staehle	Harley School
	OI	A. H. Soanes	Harley School
In Vitro Immunology	OI	R. E. Allen	NASA-MSFC
	PI	T. A. Meister	Bronx High School of Science
	OI	V. G. Galasso	Bronx High School of Science
Motor Sensory Perform	OI	R. E. Allen	NASA-MSFC
	PI	K. L. Jackson	Clear Creek High School
	OI	M. K. Kimzey	Clear Creek High School
Web Formation	PI	J. S. Miles	Lexington High School
	OI	J. M. Conley	Lexington High School
	OI	R. L. Gause	NASA-MSFC
Plant Grow/ Phototr.	OI	L. Gross	NASA-MSFC
	OI	L. M. Schaaf	Central Catholic High School
	OI	J. C. Beaton	Downey High School
	PI	J. G. Wordekemper	Central Catholic High School

Experiment	Experiment Personnel		Affiliation
	OI	D. W. Schlack	Downey High School
Cytoplasmic Streaming	OI	C. A. Cothran	NASA-MSFC
	PI	C. A. Peltz	Arapahoe High School
	OI	G. B. Scheele	Arapahoe High School
Capillary Action	PI	R. G. Johnston	Ramsey High School
	OI	R. L. Gause	NASA-MSFC
	OI	J. E. Molitor	Ramsey High School
Mass Measurements	OI	R. Head	NASA-MSFC
	PI	V. W. Converse	Harlem High School
	OI	M. J. Trumbauer	Harlem High School
Neutron Analysis	OI	R. L. Gause	NASA-MSFC
	PI	T. C. Quist	Thomas Jefferson High School
	OI	M. Stewart	Thomas Jefferson High School
Zero-G Liquid Motion	OI	R. Head	NASA-MSFC
	PI	W. B. Dunlap	Austintown Fitch High School
	OI	P. J. Pallante	Austintown Fitch High School



Pacific recovery of Skylab 2 crew on September 25, 1973.

SKYLAB 2

Launch Vehicle – Saturn 1-B.

Spacecraft Description – Command and service modules similar to Apollo, but modified for extended space flight. Modifications included an additional 1,500 pounds of propellant for the reaction control system, additional 50-gallon water tank and three 500-ampere-hour batteries, elimination of two propellant tanks for the service propulsion system, and one helium tank.

Project Objectives – Establish Skylab as an operational space station; perform needed repairs; obtain data for evaluating crew mobility and work capability in intra- and extravehicular activity; obtain medical data to determine the effects of space flight of up to 28 days; perform scientific, engineering, technological, and other experiments; obtain solar astronomy and Earth-resources data.

Spacecraft Payload – Three astronauts: Charles (Pete) Conrad, Jr., commander; Dr. Joseph P. Kerwin, science pilot; and Paul J. Weitz, pilot; repair equipment including a thermal parasol; and other items.

Project Results – Skylab 2 was launched May 25, 1973, and rendezvoused with the Skylab space station. An initial standup EVA by Weitz failed to free the jammed solar wing, but did provide clues for later attempts. Astronauts entered Skylab on May 26 and deployed a parasol-like thermal blanket through the solar-side scientific airlock. The sunshade protected Skylab's hull and temperatures within the station fell to normal ranges. With no power available from the primary solar array, other activity was reduced. Workshop electricity was drawn from the ATM arrays and from command and service module fuel cells. On June 7, Conrad and Kerwin exited the AM, cut through debris, and deployed the remaining solar wing. It immediately began producing electricity. With adequate power available, the crew completed 89 percent of their planned activities, including a second space walk by Conrad (with Weitz assisting) to retrieve film and tapes from the ATM and EREP. The crew splashed down safety southwest of San Diego June 22, 1973, after setting a new space duration record of 28 days, 49 minutes. Physical examination showed no barriers to longer missions.

Astronaut Charles Conrad, Jr., Skylab 2 commander trims hair of astronaut Paul J. Weitz, Skylab 2 pilot during a 28-day mission in Earth's orbit.



Key Spacecraft Personnel		Affiliation
PM	O. G. Smith	NASA-JSC

Experiment	Experiment Personnel	Affiliation
Radiation in Spacecraft	PI M. F. Schneider	USAF-SAMSO
Zero G on Human Cell	PI P. O. Montgomery	Southwest Medical School

RADIO ASTRONOMY
EXPLORER B/
EXPLORER 49

Launch Vehicle – Three-stage Delta with nine solid motors on first stage.

Spacecraft Description – Main structure was 36-inch cylinder, 31 inches high. Four fixed solar panels provided average power of 38 watts to a nickel-cadmium battery with a capacity of 6 ampere-hours. Most prominent features of Explorer 49 were its four 750-foot booms which deployed in space to form a giant "X" radio antenna with the spacecraft body at its center. Other appendages included a two-element dipole antenna, 120 feet long, and a 675-foot boron libration damper boom. The satellite was three-axis stabilized with a Freon-fueled attitude control system; a hydrazine system was used for velocity changes. Communications system included three transmitters and tape recorders. The lunar insertion motor was mounted at the upper end of the spacecraft body. Weight at launch, 723 pounds; in lunar orbit, 442 pounds.

Project Objectives – Investigation of low-frequency signals from galactic and extra-galactic radio sources and from the Sun, Earth, and Jupiter from the vantage point of space, where the ionisphere and extraneous Earth radio noise do not obscure them. Signal sensing range for Explorer 49 was from 0.02 to 13 MHz, compared with 0.2 to 10 MHz for its predecessor, Explorer 38. Experimenters planned to use Explorer 49's lunar occultations to pinpoint the source of signals more precisely as they appeared and disappeared on the moon's horizon during each orbit.

Spacecraft Payload – Signal sensing antenna systems; dual swept radiometer instrument; burst receivers. The spacecraft also carried facsimile cameras which focused on spheres at the ends of the 750-foot booms to record the degree of antenna bending.

Project Results – Explorer 49 was launched from Kennedy Space Center on June 10, 1973, and achieved lunar orbit on June 15 after a 20-second firing of the orbit insertion motor. Full operation of the spacecraft began approximately six weeks later.

Major Participants – Launch vehicle management, spacecraft management and manufacture, NASA Goddard Space Flight Center; launch vehicle prime contractor, McDonnell Douglas; launch operations, NASA Kennedy Space Center.

Key Spacecraft Personnel		Affiliation
PM	J. T. Shea	NASA-GSFC
PS	R. G. Stone	NASA-GSFC
MG	J. R. Holtz	NASA Headquarters
SC	N. G. Roman	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Radio Astronomy 9	PI	R. G. Stone	NASA-GSFC
Frequency V Antenna	OI	R. R. Weber	NASA-GSFC
	OI	L. W. Brown	NASA-GSFC
	OI	J. F. Clark	NASA-GSFC
Radio Burst Receiver	PI	R. G. Stone	NASA-GSFC
	OI	J. K. Alexander, Jr.	NASA-GSFC
	OI	J. Fainberg	NASA-GSFC
	OI	J. F. Clark	NASA-GSFC
	OI	H. H. Malitson	NASA-GSFC
Impedance Probe	PI	R. G. Stone	NASA-GSFC
	OI	J. L. Donley	NASA-GSFC
	OI	J. E. Guthrie	NASA-GSFC
	OI	J. A. Kane	NASA-GSFC
	OI	R. C. Somerlock	NASA-GSFC

SKYLAB 3

Launch Vehicle – Saturn I-B.

Spacecraft Description – Same as Skylab 2.

Project Objectives – Same as Skylab 2, but extend endurance up to 59 days.

Spacecraft Payload – Three astronauts: Alan L. Bean, commander; Dr. Owen K. Garriot, science pilot; and Jack R. Lousma, pilot; additional food and other supplies to replace items damaged by heat; a new thermal blanket for possible installation; and other equipment.

Project Results – Skylab 3 was launched July 28, 1973, and rendezvoused with the station. The crew began reactivating Skylab and occupied it that night. Leaking service module thrusters caused some concern during much of the mission, but did not impact duration. The crew experienced moderate illness for several days, reducing their work capacities. These symptoms disappeared as they adapted to weightlessness, and the crew ultimately exceeded most pre-mission expectations. They made extended observations with the ATM, resulting in new data on the formation and progression of solar flares and completed 39 EREP observations, 13 more than planned. Space manufacturing tests were added to the mission schedule. The crew also successfully tested maneuvering units that could be used during space walks on future programs. Three space walks were completed to install fresh film and tapes in the ATM and EREP instruments, perform other experiments, and to erect a new sun shield. Skylab experienced few mechanical problems. Six new rate gyros were installed early in the flight. The station's primary coolant loop developed a leak and was shut down after a secondary loop was activated. Capacity degradations were noted in ATM batteries, but did not impact observation schedules. The remaining solar wing continued to operate better than predicted, supplying the workshop with much of its electricity – more than 6,500 watts in sunlight. The astronauts splashed down in the Pacific Ocean southwest of San Diego September 25, 1973, setting a new space endurance record of 59 days, 11 hours, 9 minutes. Examinations showed the crew had adapted to weightlessness and experienced no major physical changes to bar extending the third mission.

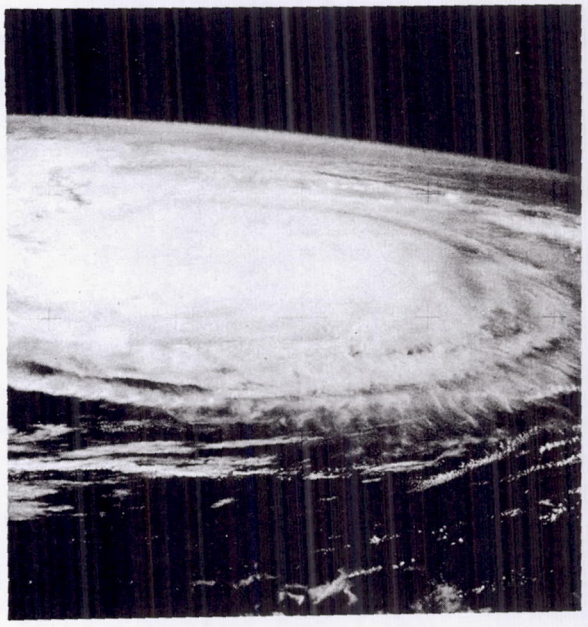
Key Spacecraft Personnel		Affiliation
PM	O. G. Smith	NASA-JSC

Experiment	Experiment Personnel	Affiliation
Circad. Rhythm, Mice	PI R. G. Lindberg	Northrop Corporation Laboratory
Circad. Rhythm, Fly	PI C. S. Pittendrigh	Stanford University
Kevsky Survey	PI W. L. Kraushaar	University of Wisconsin

Skylab 3 looks at the Earth. Metropolitan Chicago, surrounded by Hammond and Gary, Indiana; Aurora and Joliet, Illinois, and East Chicago.



Hurricane Ellen over Atlantic Ocean on September 20, 1973, with very large circular, counter-clockwise structure pattern.



INTELSAT IV F-7

Launch Vehicle – Atlas-Centaur: Atlas booster developed 430,000 pounds with two 185,000 main engines and one 60,000-pound sustainer. Centaur stage's two engines developed 15,000 each. A new Centaur guidance and electronic system featuring a new, onboard high-speed digital computer was introduced in 1973. Vehicle was 132 feet high.

Spacecraft Description – Drum-shaped; 17 feet high, eight feet in diameter. Weight at launch, about 3,100 pounds. Weight in orbit, about 1,500 pounds. Drum covered with 45,000 solar cells providing approximately 570 watts of power. Solid propellant SVM-4A apogee kick motor mounted on spacecraft developed 10,000 pounds thrust.

Project Objectives – Fourth-generation satellite to increase capacity of Intelsat's global communications network. Each Intelsat IV carried 5,000 to 6,000 two-way telephone calls or 12 channels of color TV.

Spacecraft Payload – The communications subsystem was mounted on a mechanically despun platform and included six antennas: two 50-inch dishes for spotbeam transmission to Earth and a cluster of four conical horn antennas – two for wideband transmission to Earth, two for reception from Earth. Antennas were connected to a 12-channel microwave repeater system that provided power amplification of each channel individually. Each 50-inch dish could be directed to any spot on Earth within the spacecraft's line of sight.

Project Results – Flight 7 was launched from Cape Canaveral, Fla. on August 23, 1973, into synchronous orbit. The satellite was placed in service on September 14, 1973, over the Atlantic at 29.8 degrees west longitude.

Major Participants – Spacecraft management, COMSAT Corp. for Intelsat consortium; Spacecraft prime contractor, Hughes Aircraft Co; Launch vehicle management, NASA Lewis Research Center; Launch vehicle prime contractor, General Dynamics/Convair; Apogee motor, Aerojet-General; Major suppliers from 10 countries made up the international contractor team.

INTERPLANETARY MONITORING PLATFORM J/ EXPLORER 50

Launch Vehicle – Two-stage Delta with six solid motors.

Spacecraft Description – Sixteen-sided drum, 53 inches in diameter and 62 inches high. Upper compartment of drum contained experiment and spacecraft support equipment; lower compartment contained solid propellant apogee kick motor. Two ten-foot booms with magnetometers deployed in orbit, as did two four-foot attitude control booms. Eight small RF antennas extended radially from the spacecraft. The spacecraft was spin stabilized at about 23 rpm; attitude control was by a cold gas monopropellant system using Freon 14. Telecommunications equipment included two transmitters, a convolutional encoder, and two command receivers. Weight: 818 pounds.

Project Objectives – IMP-J was the tenth and last in a series of platforms launched to investigate the Earth's radiation environment over the entire 11-year solar cycle which began in 1963. Twelve instruments measured energetic particles, plasmas, magnetic fields and electric fields. Operating orbital IMP's sometimes were able to view solar events from different vantage points in space to provide additional insight. IMP-J also carried as an engineering experiment, a solar panel using new violet solar cells developed by COMSAT Labs, and an experimental data multiplex unit using new types of microcircuitry and coding systems.

Spacecraft Payload – Twelve experiments: cosmic ray telescope; cosmic ray accelerometer; ion-electron detector; electron-isotope detector; energetic particle detector; charged particle counter; "Faraday cup" plasma measurement system; low-energy particle detector; plasma analyzer; boom magnetometers; DC field biaxial antennas; and AC electric and magnetic field antennas.

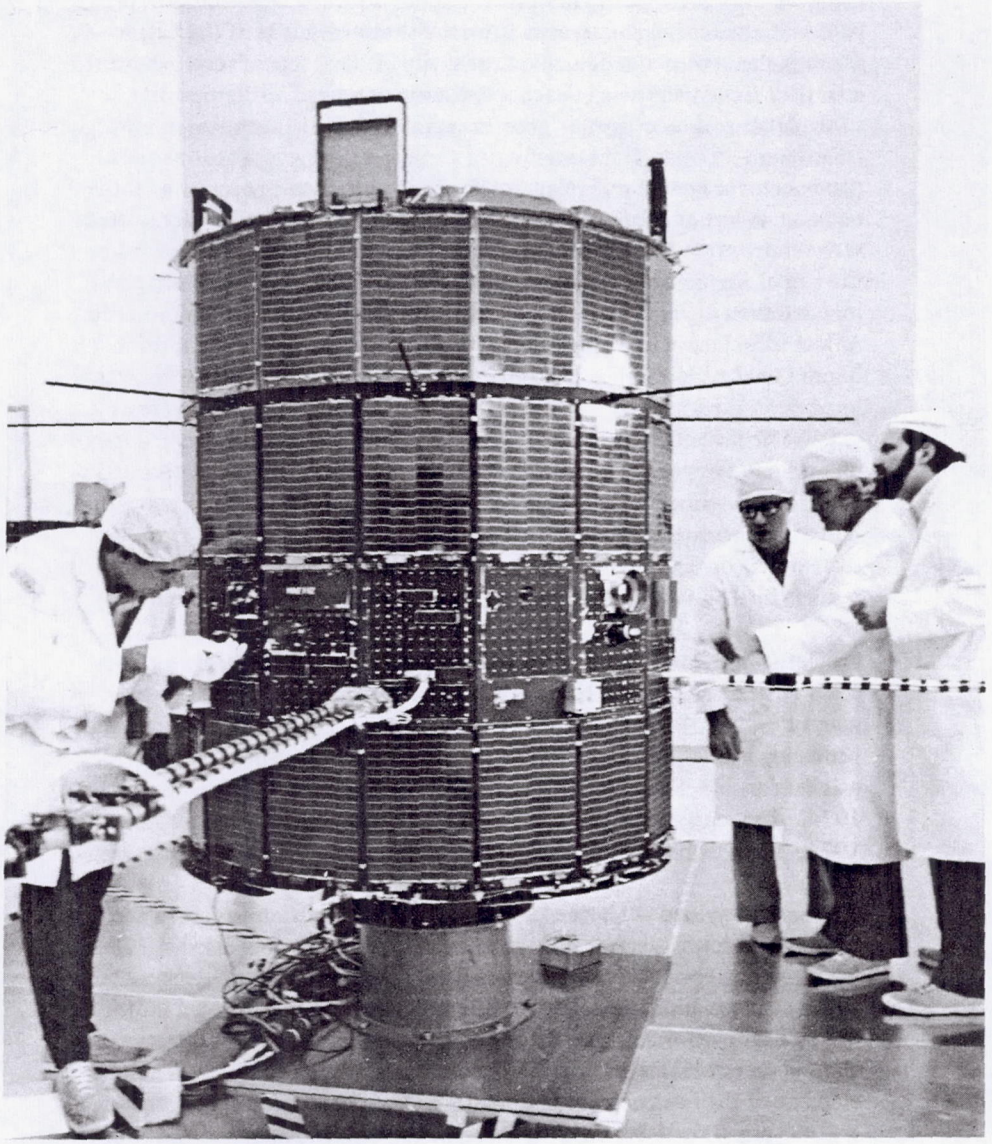
Project Results – Launched from Kennedy Space Center on October 25, 1973, into an elliptical orbit of about 140,000 by 280,000 km.

Major Participants – Launch vehicle and spacecraft management, NASA Goddard Space Flight Research Center; space vehicle prime contractor, EMR Aerospace Sciences; launch vehicle prime contractor, McDonnell Douglas; launch operations, NASA Kennedy Space Center.

Key Spacecraft Personnel		Affiliation
PM	M. A. Davis	NASA-GSFC
PS	J. H. King	NASA-GSFC
CO	J. H. Trainor	NASA-GSFC
MG	J. R. Holtz	NASA Headquarters
SC	E. R. Schmerling	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Tri-Axis Magnetometer	PI	N. F. Ness	NASA-GSFC
	OI	C. S. Scearce	NASA-GSFC
	OI	J. B. Seek	NASA-GSFC
Solar Plasma, Faraday Cup	PI	H. S. Bridge	Massachusetts Institute of Technology
	OI	A. J. Lazarus	Massachusetts Institute of Technology
	OI	J. H. Binsack	Massachusetts Institute of Technology
	OI	E. F. Lyon	Massachusetts Institute of Technology
Solar Ions + Electrons, 100 keV	PI	G. Gloeckler	University of Maryland
	OI	C. Y. Fan	University of Arizona
	OI	D. K. Hovestadt	MPI-Extraterrestrial Physics
Electrons + Protons, 25 eV-50 keV	PI	L. A. Frank	University of Iowa
Electrons + Protons, Telemetry Gr.	PI	D. J. Williams	NOAA-ERL
	OI	C. O. Bostrom	Applied Physics Laboratories
	OI	J. H. Trainor	NASA-GSFC
Electrons + H + HE Solid State Telemetry	PI	E. C. Stone	California Institute of Technology
	OI	R. F. Vogt	California Institute of Technology
	CO	W. E. Althouse	California Institute of Technology
Cosmic Ray Nuclear Composition	PI	J. A. Simpson	University of Chicago
	OI	M. Garcia-Munoz	University of Chicago
	CO	G. Lentz	University of Chicago
Particle Telemetry + Geiger Mueller Tubes	PI	S. M. Krimigis	Applied Physics Laboratories
	OI	T. P. Armstrong	University of Kansas
	OI	J. A. Van Allen	University of Iowa
Cosmic Rays (E vs DE/DX)	PI	F. B. McDonald	NASA-GSFC
	OI	D. E. Hagge	Unknown
	OI	B. J. Teegarden	NASA-GSFC
Plasma, Electromagnetic Analyzer	PI	S. J. Bame	Los Alamos Science Laboratory
	OI	J. R. Asbridge	Los Alamos Science Laboratory
Direct Current Electric Fields	PI	T. L. Aggson	NASA-GSFC
	OI	J. P. Heppner	NASA-GSFC
Alternating Current Electric, Magnetic Fields	PI	D. A. Gurnett	University of Iowa
	OI	T. L. Aggson	NASA-GSFC
	OI	G. W. Pfeiffer	University of Iowa

Experiment	Experiment Personnel	Affiliation
Deuterium in Solar W.	PI F. Scherb	University of Wisconsin
Low Energy Solar Electrons	PI K. A. Anderson	University of California, Berkeley
Cosmic Ray Electrons	PI P. Meyer	University of Chicago



The tenth and last in the NASA series of IMP's designed to investigate the Earth's radiation environment over an entire solar cycle. Here the spacecraft is being checked out prior to launch on October 25, 1973.

MARINER 10 (Mariner/ Venus/ Mercury)

Launch Vehicle – Atlas-Centaur SLV-3C.

Spacecraft Description – Mariner 10's basic structure was a 40-pound, eight-sided forged magnesium framework with eight electronics compartments. The framework was 54 ½ inches diagonally and 18 inches deep. Two solar panels, each 106 inches long and 38 inches wide, were attached by outriggers to the top of the octagon. The panels supported 54.9 square feet of solar cell area. A spherical propellant tank occupied the central cavity of the octagon; the nozzle of the spacecraft's 50-pound-thrust, liquid monopropellant hydrazine engine projected from the sunward side of the octagon through the center of a deployable heat shield. Two sets of reaction-control jets, with three pairs of jets in each set, were mounted at the tips of the solar panels and on outrigger structures supporting high-gain antenna and magnetometer booms. Titanium bottles carried nitrogen gas for the dual attitude control system and regulators were mounted on the top ring of the octagon. A low-gain omni antenna was formed by two conical plates slotted into the outer end of a pair of concentric tubes extending 112 inches from the top of the octagon. They were one inch and 2 ¼ inches in diameter. A motor-driven high-gain antenna consisted of an aluminum honeycomb dish reflector 54 inches in diameter and parabolic in cross-section, and a jointed boom attached to the octagon by an outrigger. A Canopus star tracker was located on the upper ring of the octagon. Acquisition sun sensors were at the tips of the solar panels. Five of Mariner 10's eight electronics compartments were temperature controlled by louver assemblies on the outer surfaces. The interior was insulated by multilayer thermal blankets at top and bottom. A sunshade, deployed after launch, protected the side of the spacecraft facing the sun. Launch weight was about 1,108 pounds, including 64 pounds of fuel and nitrogen gas, and 172 pounds of instruments.

Project Objectives – Mariner 10 was to fly past Venus, taking the first pictures of the planet and measuring its ultraviolet markings. Using Venus' gravity, Mariner 10 was then to fly on to Mercury, taking more pictures and providing man's first close view of the planet nearest the Sun. Venus flyby was set for Feb. 5, 1974, and the first Mercury flyby was to occur March 29, 1974. A second opportunity to fly past Mercury was to occur Sept. 22, 1974. More than 8,000 pictures of the two planets were expected.

Spacecraft Payload – Mariner 10 carried instrumentation for six experiments. A seventh – celestial mechanics and radio science – used signals from the spacecraft's transmitters, S-Band and X-Band. Two identical television cameras and their telescope assemblies were mounted on a motor-driven scan platform on the shaded side of the spacecraft. An ultraviolet airglow spectrometer was positioned alongside the TV cameras. A second element of the ultraviolet experiment, the UV occultation spectrometer, and a charged particle telescope were body-fixed to the octagon. A 20-foot-long hinged boom supported two magnetometers, one at the end and one about 13 feet from the spacecraft. The boom was deployed perpendicular to the spacecraft's long axis. Plasma detectors were mounted on a short, motor-driven boom to provide unobstructed viewing beyond the spacecraft end of the boom.

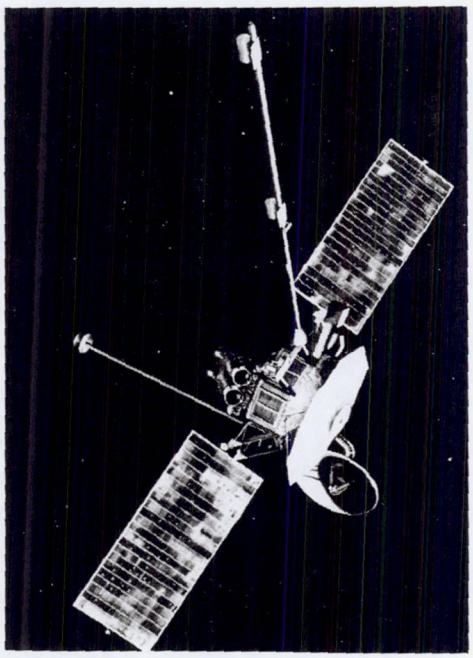
Project Results – Mariner 10 was successfully launched from Kennedy Space Center Nov. 3, 1973. It took test pictures of Earth and the moon during early hours of the flight. Some problems were encountered with heaters on Mariner 10's cameras, and the cameras were left on to prevent freezing during the interplanetary cruise.

Major Participants – Program management, Office of Space Science, NASA Headquarters; Project management, NASA Jet Propulsion Laboratory, California Institute of Technology; Launch vehicle management, NASA Lewis Research Center; Launch operations, NASA Kennedy Space Center; Spacecraft prime contractor, The Boeing Co.; Launch vehicle prime contractor, General Dynamics.

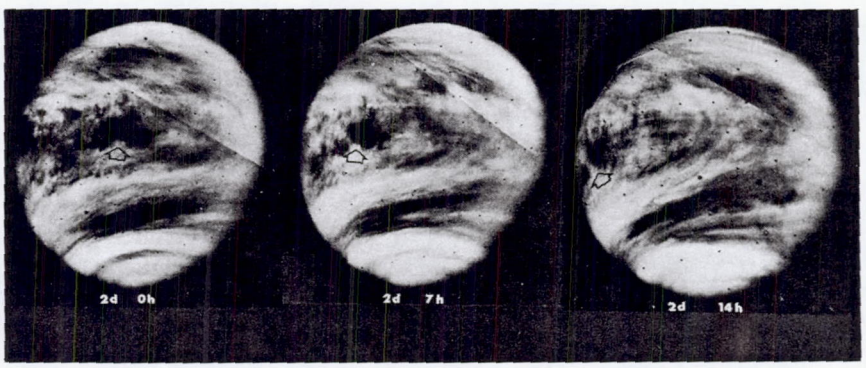
Key Spacecraft Personnel		Affiliation
PM	W. E. Giberson	NASA-JPL
MG	N. W. Cunningham	NASA Headquarters
CO	F. Briston	NASA-JPL
SC	S. E. Dwornik	NASA Headquarters
PS	J. A. Dunne	NASA-JPL

Experiment	Experiment Personnel		Affiliation
Telemetry Photography	PI	B. C. Murray	California Institute of Technology
	OI	M. J. S. Belton	Kitt Peak National Observatory
	OI	G. P. Kuiper	University of Arizona
	OI	V. E. Suomi	University of Wisconsin
	OI	N. J. Trask, Jr.	U.S. Geological Survey
	OI	D. F. Gault	NASA-ARC
	OI	B. W. Hapke	University of Pittsburgh
	OI	M. E. Davies	Rand Corporation
	OI	B. T. O'Leary	Princeton University
Radio Science	OI	G. S. Levy	NASA-JPL
	OI	I. I. Shapiro	Massachusetts Institute of Technology
	OI	G. Fjeldbo	NASA-JPL
	OI	A. J. Kliore	NASA-JPL
	PI	H. T. Howard	Stanford University
	OI	J. D. Anderson	NASA-JPL
Scanner Electrostatic Analyzer	PI	H. S. Bridge	Massachusetts Institute of Technology
	OI	J. H. Binsack	Massachusetts Institute of Technology
	OI	A. J. Lazarus	Massachusetts Institute of Technology
	OI	S. Olbert	Massachusetts Institute of Technology

Experiment	Experiment Personnel	Affiliation
	OI S. J. Bame	Los Alamos Science Laboratory
	OI M. D. Montgomery	Los Alamos Science Laboratory
	OI A. J. Hundhausen	National Center for Atmospheric Research
	OI J. R. Asbridge	Los Alamos Science Laboratory
	OI K. W. Ogilvie	NASA-GSFC
	OI L. F. Burlaga	NASA-GSFC
	OI R. E. Hartle	NASA-GSFC
	OI C. W. Snyder	NASA-JPL
	OI G. L. Siscoe	University of California, Los Angeles
Fluxgate Magnetometer	PI N. F. Ness	NASA-GSFC
	OI K. W. Behannon	NASA-GSFC
	OI R. P. Lepping	NASA-GSFC
	OI Y. C. Whang	Catholic University of America
EUV Spectroscopy	PI A. L. Broadfoot	Kitt Peak National Observatory
	OI M. B. McElroy	Harvard University
	OI M. J. S. Belton	Kitt Peak National Observatory
Iridium Radiometry	OI E. D. Miner	NASA-JPL
	OI D. Morrison	University of Hawaii
	OI G. Munch	California Institute of Technology
	OI G. Neugebauer	California Institute of Technology
	OI J. M. Saari	Boeing Scientific Research Laboratory
	PI S. C. Chase, Jr.	Santa Barbara Research Center
Energetic Particles	PI J. A. Simpson	University of Chicago
	OI J. E. Lamport	University of Chicago



Artist's conception of Mariner 10, NASA's first dual planet mission, launched November 3, 1973. Mariner 10 observed both Venus and Mercury.



On February 7, 1974 Mariner 10 flew past the Planet Venus and returned these photographs, 10:00 a.m., 5:00 p.m. and midnight EDT. Size of the feature indicated by arrows is about 620 miles. The satellite was launched on November 3, 1973.

ITOS F/NOAA 3

Launch Vehicle – Delta two-stage (Model 300) with three solids strapped to the first stage.

Spacecraft Description – Box-shaped, 40 x 40 x 49 inches, and about 14 feet wide with solar arrays deployed. Spacecraft was three-axis stabilized, Earth-oriented, with momentum wheels controlling pitch attitude. Three solar arrays with a total area of nearly 50 square feet provided about 250 watts of power. Communications: a UHF antenna for spacecraft command and telemetry; an S-band transmitter for real-time data transmission; a VHF transmitter for transmission of stored data. An onboard tape recorder had a video storage capacity of 9 minutes. Weight: 750 pounds.

Project Objectives – Provide visible and infrared images of cloud cover, snow and ice, and the sea surface, and gather information on temperatures and moisture at various levels in the Earth's atmosphere to aid in improved weather forecasting; gather local area radiance data for calculation of temperatures. The data provided a basis for improved local storm warnings, better predictions of West Coast weather coming from the Pacific, and more accurate aviation and shipping weather forecasts.

Spacecraft Payload – Scanning radiometer system provided both visible and IR data; visible channel observed sunlit portions of Earth, scanning a 2,000-n.m. swath providing images with 2 n.m. resolution. IR channel provided cloud cover pictures day and night. Very high resolution radiometer provided similar data in lesser amounts but at a resolution of 1/2 n.m. Vertical temperature profile radiometer sounded a "tunnel" in the atmosphere to measure IR radiation at six atmospheric levels and at the Earth's surface or cloud tops. Solar proton monitor detected the arrival of energetic particles in the vicinity of Earth at the polar regions for use in solar storm predictions.

Project Results – ITOS-E was launched from the Western Test Range on July 16, 1973. A malfunction in the second stage attitude control prevented the spacecraft from achieving orbit. ITOS-F was launched from the Western Test Range on November 6, 1973 into a circular, 1,500-km polar orbit, whereon it was designated NOAA 3.

Major Participants – System manager and operator, National Oceanic and Atmospheric Administration; spacecraft and launch vehicle management, NASA Goddard Space Flight Center; spacecraft prime contractor, RCA; launch vehicle prime contractor, McDonnell Douglas; launch operations, NASA Kennedy Space Center; Unmanned Launch Operations, Western Test Range.

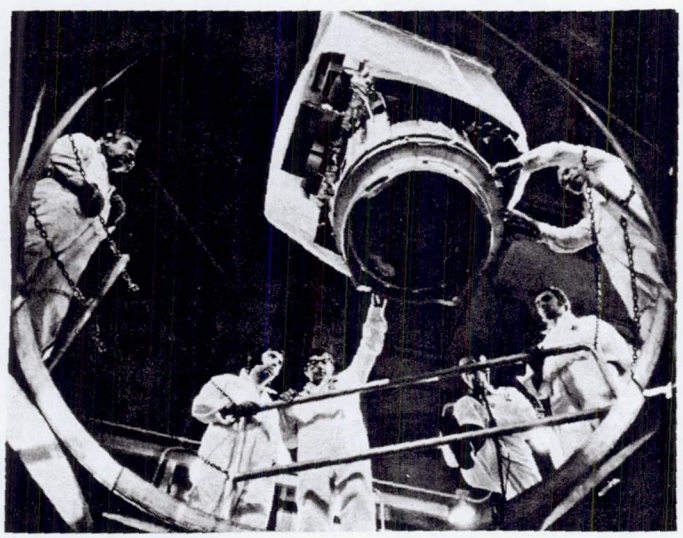


November 6, 1973 ITOS-F launch by Delta 98.

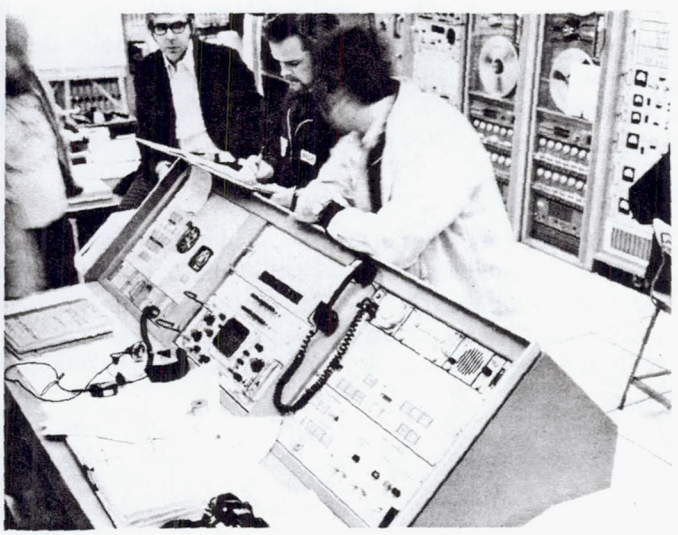
Key Spacecraft Personnel		Affiliation
ITOS F/NOAA 3		
PM	S. Weiland	NASA-GSFC
PS	I. L. Goldberg	NASA-GSFC
CO	C. M. Hunter	NASA-GSFC
SC	Unknown	Unknown

Experiment	Experiment Personnel		Affiliation
ITOS F/NOAA 3			
Solar Proton Monitor	PI	D. J. Williams	NOAA-ERL
	OI	H. H. Sauer	NOAA-ERL
Scanning Radiometer	PI	Ness Staff	NOAA-NESS
Very High Resolution Radiometer	PI	Ness Staff	NOAA-NESS
	CO	S. Weiland	NASA-GSFC
Vertical Temperature Profile Radiation	PI	Ness Staff	NOAA-NESS

Weather satellite ITOS-F/NOAA-3 during checkout.



First data read-out at Cape Kennedy from ITOS-F.



SKYLAB 4

Launch Vehicle – Saturn I-B.

Spacecraft Description – Same as Skylabs 2 and 3.

Spacecraft Payload – Three astronauts: Gerald P. Carr, commander; Dr. Edward G. Gibson, science pilot; William R. Pogue, pilot; film and tapes; coolant servicing kit; Kohoutek observation camera; and other items.

Project Objectives – Same as Skylabs 2 and 3, but extend endurance up to 84 days and add observations of Comet Kohoutek with various cameras and instruments.

Project Results – Skylab 4 was launched November 16, 1973, after a 10-day delay to replace cracked stabilizing fins on the launch vehicle. Rendezvous and docking were normal. The crew reactivated Skylab, reserviced the primary coolant loop, and established a daily routine including intensive exercise. Initial nausea and vomiting by Pogue disappeared after he adjusted to weightlessness. Medical, engineering, scientific, and technological experiments were continued or repeated. Four extravehicular activities were successfully completed. The first, by Pogue and Gibson, on November 22 lasted six hours, 33 minutes and included installation of film and tapes in the ATM and EREP, and repairs to lock a malfunctioning antenna in place and open an instrument door. The second by Pogue and Carr, on December 25, was the longest EVA on record, seven hours and one minute, and included Kohoutek observations and photography, and retrieval/installation of ATM and EREP films and tapes. The third, on December 29 by Gibson and Carr, lasted three hours and 29 minutes, and included additional Kohoutek and solar observations. The final EVA by Pogue and Carr on February 3 lasted five hours and 19 minutes, and included final experiment closeout and photography, retrieval of films and tapes, retrievals of various experiments and samples previously deployed, and deployment of a meteoroid collection device for possible retrieval in the future. During the last half of the mission, intermittent malfunctions of a control gyro caused concern and threatened duration. However, the problem cleared spontaneously. Some EREP passes were deleted, however, because of concern over Skylab's attitude control. The crew splashed down in the Pacific Ocean southwest of San Diego on February 8, 1974, after establishing a record 84 days, one hour and 16 minutes in space. Their physical condition was excellent.

Major Program Participants – Program management; NASA Office of Manned Space Flight. Orbital cluster and launch vehicle management: Marshall Space Flight Center. Command and service module management, flight operations, crew training equipment, life sciences, Earth resources, and other experiment management: Johnson Space Center. Launch operations: Kennedy Space Center. ATM fabrication: Marshall Space Flight Center. Principal contractors and subcontractors: OWS, McDonnell Douglas; MDA, Martin Marietta; automatic checkout equipment, General Electric; command and service modules, Rockwell International; launch vehicle instrument units, IBM; Saturn V first stage, Boeing; Saturn V second stage, Rockwell International; Saturn I-B first stage, Chrysler; S-IVB, McDonnell Douglas.

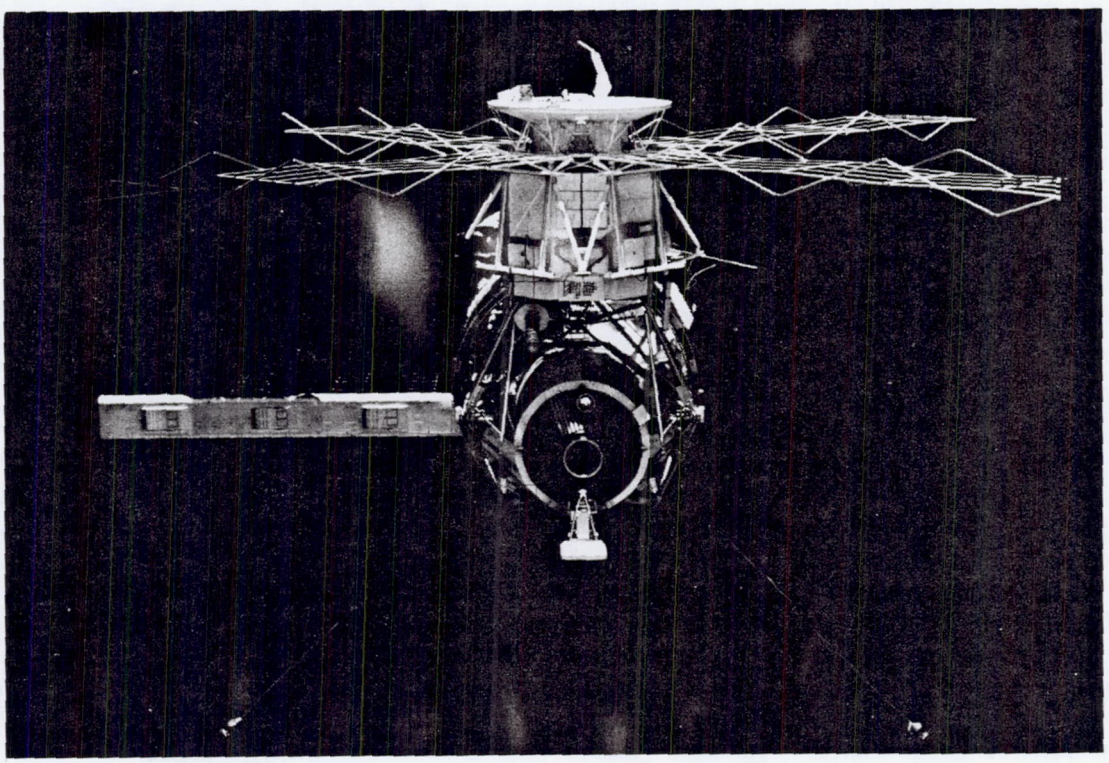


Key Spacecraft Personnel		Affiliation
PM	O. G. Smith	NASA-JSC

Experiment	Experiment Personnel	Affiliation
Potato Respiration	PI B. W. Pince	Space Defense Corporation
	OI F. A. Brown, Jr.	Northwestern University
CSM-3, Body Fluid Bioassay	PI C. S. Leach	NASA-JSC
Ultraviolet Camera	PI G. R. Carruthers	U.S. Naval Research Laboratory
	OI J. L. Page	NASA-JSC

Pogue holds onto ceiling as he prepares to force another trash bag further down into the airlock with Carr in the foreground, assisting.

This view of Skylab space station was taken from Skylab 4 command and service modules. Inside the command module were astronauts Gerald P. Carr, commander, Edward G. Gibson, science pilot and William R. Pogue, pilot.



ATMOSPHERE EXPLORER C/ EXPLORER 51

Launch Vehicle – Two-stage Delta with nine solid motors.

Spacecraft Description – Cylinder 53 inches in diameter, 45 inches high. Solar cells on top of and around the cylinder provided 100 watts of electric power to nickel-cadmium batteries for 60 to 120 minutes per orbit. Spin-stabilized in either Earth-pointing or zenith-pointing modes, with variable rates from 0.5 to 10 rpm. Systems used momentum wheel, magnetic torquers and nutation dampers. Communications system included omni-directional S-band and VHF antennas, S-band and VHF transmitters. Data could be sent in real time or stored by tape recorders. A new orbit adjust propulsion system carried 370 pounds of monopropellant hydrazine to alter the spacecraft's perigee by as much as 21 miles during the first six months of the mission, and as much as 180 miles thereafter. Weight: 1,450 pounds.

Project Objectives – Exploration of energy transfer, atomic and molecular processes, and chemical reactions in the atmospheric region from 72 to 120 miles and above; provide data for construction of complete models of Earth's outer environment; investigate thermal processes and mechanisms that are effects of the atmosphere's absorption of solar ultraviolet radiation; examine particle flux, plasma densities, temperature, and magnetic fields in the lower regions of the atmosphere where energy dissipation occurs. Explorer 51 was the first in a series of three second-generation Atmosphere Explorers with these objectives.

Spacecraft Payload – Fourteen science instruments: UV photometer; cylindrical electrostatic probe; positive ion mass spectrometer; atmosphere density accelerometer; photoelectron spectrometer; retarding potential analyzer; visual airglow photometer; extreme solar UV photometer; solar extreme UV spectrophotometer; magnetic ion mass spectrometer; low-energy electron spectrometer; open-source neutral mass spectrometer; neutral atmosphere composition spectrometer; and neutral atmosphere temperature spectrometer.

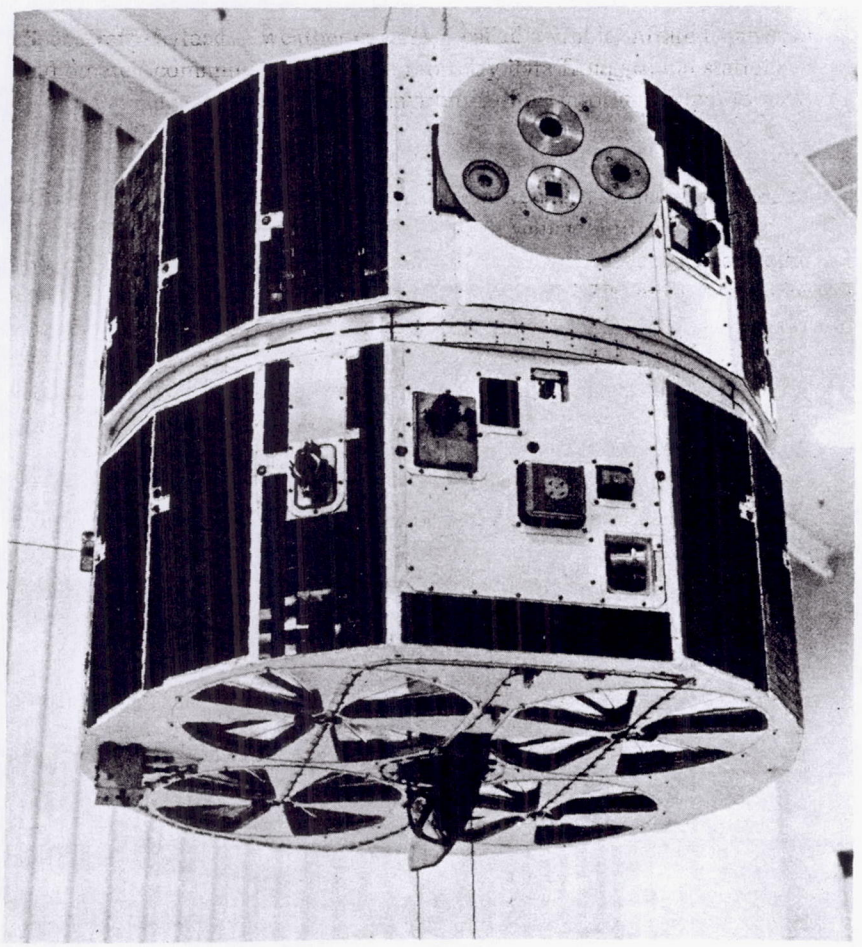
Project Results – AE-C was launched December 16, 1973, from the Western Test Range into an orbit of 150 by 4,200 km, whereon it was designated Explorer 51.

Major Participants – Launch vehicle and spacecraft management, NASA Goddard Space Flight Center; spacecraft prime contractor, RCA; orbit adjust propulsion system, TRW; launch vehicle prime contractor, McDonnell Douglas; launch operations, NASA Unmanned Launch Operations at the Western Test Range.

Key Spacecraft Personnel		Affiliation
PM	D. Grimes	NASA-GSFC
PS	N.W. Spencer	NASA-GSFC
MG	F.W. Gaetano	NASA Headquarters
SC	E.R. Schmerling	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Cylindrical Electrostatic Probe (CEP)	PI	L. H. Brace	NASA-GSFC
	OI	R. F. Theis	NASA-GSFC
Tri-Axis Occultation System (MESA)	PI	K. S. W. Champion	USAF Geophysics Laboratory
	OI	F. A. Marcos	USAF Geophysics Laboratory
Photoelectric Spectrometer (PES)	PI	J. P. Doering	Johns Hopkins University
	OI	C. O. Bostrom	Applied Physics Laboratory
Retard Potel. Analyzer (RPA)	PI	W. B. Hanson	University of Texas, Dallas
	OI	D. R. Zuccaro	University of Texas, Dallas
	OI	S. Sanatani	University of Texas, Dallas
Extreme Solar UV Monitor (ESUM)	PI	D. F. Heath	NASA-GSFC
	OI	J. F. Osantowski	NASA-GSFC
Solar EUV Spectrometer (EUVS)	PI	H. E. Hinteregger	USAF Geophysics Laboratory
	OI	D. E. Bedo	USAF Geophysics Laboratory
	OI	L. A. Hall	USAF Geophysics Laboratory
	OI	C. W. Chagnon	USAF Geophysics Laboratory
	OI	J. E. Manson	USAF Geophysics Laboratory
Open Source Spectrometer (OSS)	PI	A. O. C. Nier	University of Minnesota
	OI	F. J. Heyden	Manila Observatory
	OI	K. Mauersberger	University of Minnesota
	OI	W. E. Potter	University of Minnesota
Neutrino Atmospheric Composition Experiment (NACE)	PI	D. T. Pelz	NASA-GSFC
	OI	C. A. Reber	NASA-GSFC
	OI	G. R. Carignan	University of Michigan
Neutrino Atmospheric Temperature Experiment (NATE)	PI	N. W. Spencer	NASA-GSFC
	OI	G. R. Carignan	University of Michigan
Magnetic Ion Mass Spectrometer (MIMS)	PI	J. H. Hoffman	University of Texas, Dallas
Bennett Ion Mass Spectrometer (BIMS)	PI	H. C. Brinton	NASA-GSFC
	OI	L. R. Scott	NOAA-NESS
	OI	M. W. Pharo, III	NASA-GSFC
	OI	H. A. Taylor, Jr.	NASA-GSFC

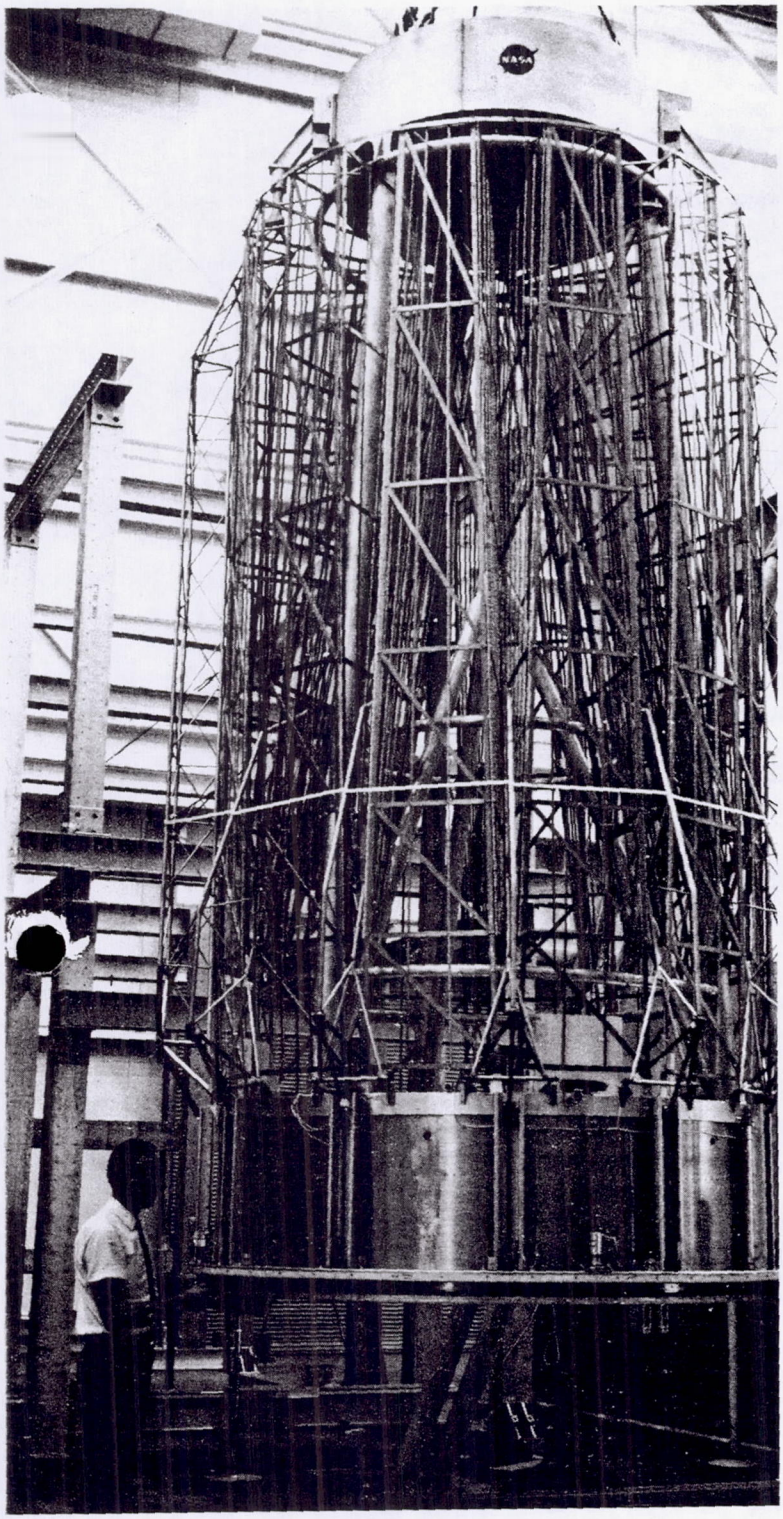
Experiment	Experiment Personnel	Affiliation
Low Energy Electrostatic Experiment (LEE)	PI R. A. Hoffman	NASA-GSFC
	OI D. S. Evans	NOAA-ERL
	OI J. L. Burch	Southwest Research Institute
Ultraviolet Nitric Oxide Experiment (UVNO)	PI C. A. Barth	University of Colorado
Visible Airglow Experiment (VAE)	PI P. B. Hays	University of Michigan
	OI G. G. Shepherd	York University
Cold Cathode Pressure Gauge (PSB)	PI C. J. Rice	Aerospace Corporation
Capacity Pressure Gauge (PSA)	PI C. J. Rice	Aerospace Corporation
Magnetometer (MAG)	PI A. J. Zmuda	Applied Physics Laboratory
Temperature Alarm (TAL)	PI P. Caruso	NASA-GSFC

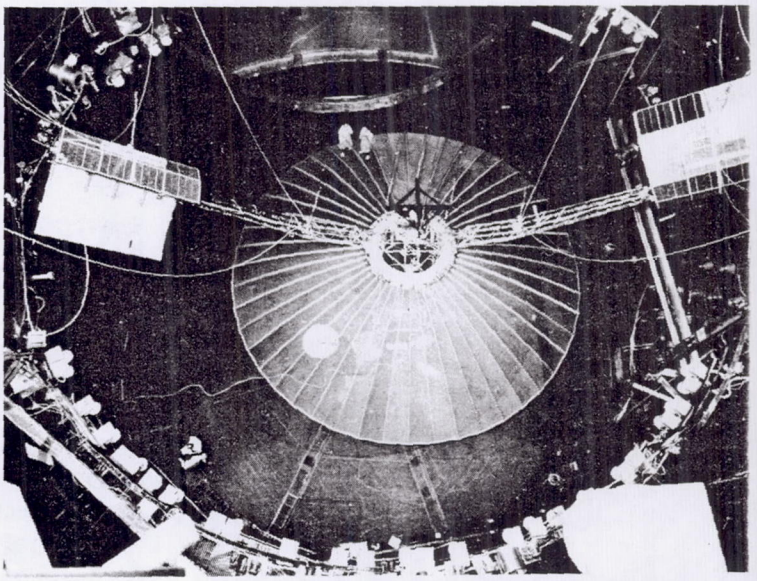


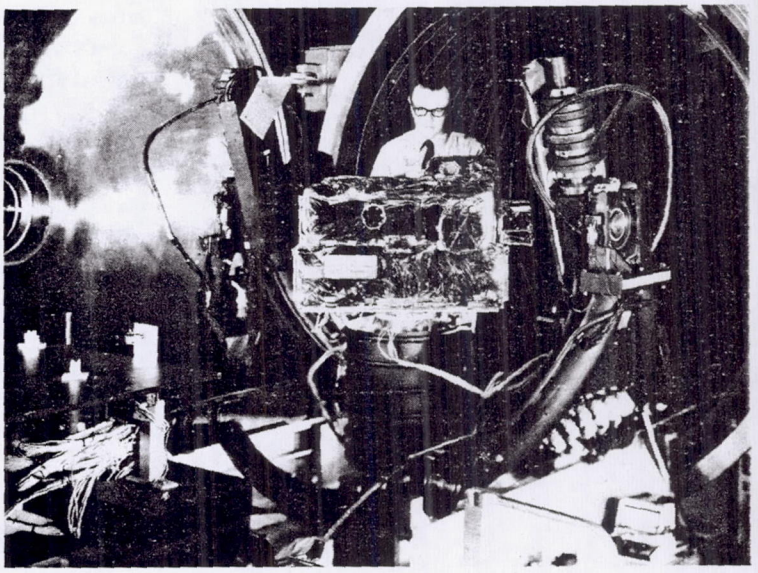
Atmosphere Explorer-C/Explorer 51 was launched on December 16, 1973.

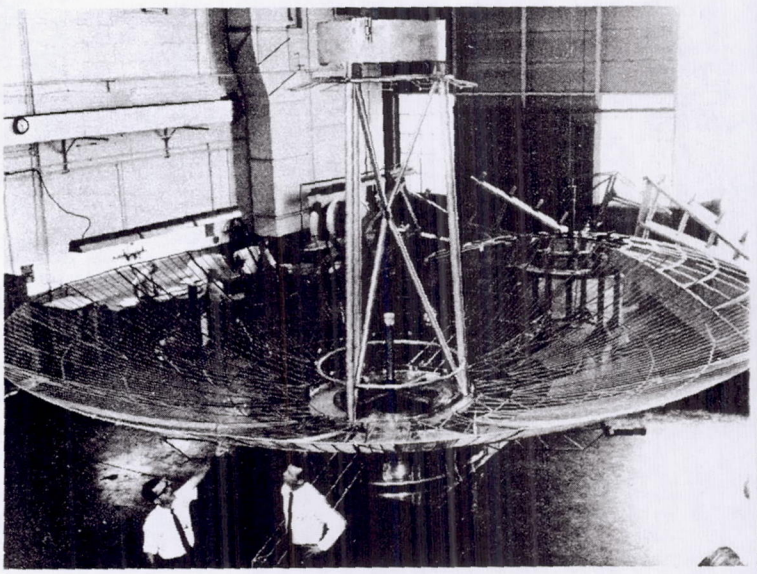
1973

1974









On May 30, 1974, NASA launched the Applications Technology Satellite-F (ATS-F) with its 16-foot diameter antenna structure capable of linking both ground stations and orbiting spacecraft. The Applications Technology Satellite served as a space-borne communications switchboard. Shown here are test procedures prior to launch.

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SAN MARCO C-2

Launch Vehicle – Scout.

Spacecraft Description – Scout.

Project Objectives – Measure the diurnal variations of the equatorial neutral atmosphere density, composition and temperature.

Spacecraft Payload – Neutral atmosphere composition experiment was flown at equatorial latitudes to determine the concentrations and temporal (including diurnal) fluctuations of the following neutral upper atmosphere constituents–argon, molecular and atomic oxygen, molecular nitrogen, and helium. The measurements obtained were correlated with appropriate atmospheric Explorer C data; a magnetic mass spectrometer was used.

Neutral atmosphere temperature experiment was flown to determine by direct measurement the temperature and density of molecular nitrogen at several altitudes in the upper atmosphere. The data obtained were used to study temporal fluctuations, and they were also correlated with atmospheric Explorer C measurements. The sensor was a small omegatron tuned to measure molecular nitrogen, and had a specially shaped aperture. Temperature was measured during a spin-scan by observing the response as a function of angle with the satellite velocity vector.

Project Results – San Marco C-2, also known as San Marco 4, was launched from the Italian-operated San Marco launch platform in the Indian Ocean, three miles off the coast of Kenya, Africa on February 18, 1974. The spacecraft was placed into an orbit of approximately 582 miles apogee and 147 miles perigee; inclination to the equator 2.9 degrees; period 95.5 minutes. The spacecraft decayed on May 4, 1976.

Major Participants – Centro Ricerche Aerospazial, the Italian space agency, spacecraft management; NASA Langley Research Center, launch vehicle management; Ling-Temco-Vought, launch vehicle prime contractor.

Key Spacecraft Personnel	Affiliation
PM A.J. Caporale	NASA-GSFC
PS G.P. Newton	NASA-GSFC
MG J.R. Holtz	NASA Headquarters
SC E.R. Schmerling	NASA Headquarters

Experiment	Experiment Personnel	Affiliation
Drag Balance Experiment	PI L. Broglio	National Resources Council, Italy
Neutral Atmosphere Composition	PI G.P. Newton OI G. Carignan	NASA-GSFC Univ. of Michigan
Neutral Atmosphere Temperature	PI N.W. Spencer	NASA-GSFC

UK-X4 (Miranda)

Launch Vehicle – Four stage Scout. This was the fourth United Kingdom launch on a Scout vehicle and the 30th consecutive successful launch of the Scout vehicle.

Spacecraft Description – The United Kingdom X4 spacecraft was a rectangular structure with two solar array panels extending from the main body. The satellite was 835 millimeters (33 inches) in height, and 665 millimeters (26 inches) wide across its faces. With its solar array deployed, its span was 2,500 mm (98.5 inches).

Project Objectives – Five experiments flown on three-axis stabilized spacecraft to demonstrate the technology involved in the design and manufacture of this type of experiment platform for use on small spacecraft.

Spacecraft Payload – The primary experiment was an attitude control subsystem designed to demonstrate attitude control accuracy of better than three arc minutes, using only gas jets. Three other experiments on sensor operation: an infrared horizon sensor, a single-axis star sensor and an albedo horizon sensor with digital output, are also aboard. A fifth experiment was to determine the degradation of silicon solar cells in orbit.

Project Results – UK-X4 (Miranda) was launched on March 8, 1974 from the Air Force Western Test Range at Vandenberg AFB, Calif. into a circular orbit.

Major Participants – The X4 spacecraft was built by Hawker Siddeley Dynamics Ltd., for the Ministry of Defence (Procurement Executive), acting on behalf of the Department of Trade and Industry. The principal subcontractor was the Marconi Co., Portsmouth, England. NASA direction for the project was through the Office of Space Science, NASA Headquarters. Launch management responsibility, NASA Langley Research Center. Launch vehicle was built by Vought System Div., LTV Aerospace Corp. Launch Operations, Vought Systems Div., LTV Aerospace Corp. under the technical direction of the Air Force Western Test Range and supported by Kennedy Space Center's Western Test Range Operations Div., Lompoc, Calif.

WESTAR 1 and 2

Launch Vehicle – Delta "straight eight" (see SMS-1 launch vehicle description).

Spacecraft Description – Main body was a spin-stabilized cylinder 6.3 feet in diameter. Atop the body was a spoon-shaped mesh antenna, despun in orbit to point continuously at Earth. Total height of the spacecraft was 11.8 feet. Westar weighed 1,265 pounds at launch. More than 20,000 solar cells covered the exterior of the cylinder to provide more than 300 watts of power at beginning of life. Attitude control and station-keeping was achieved by redundant hydrazine systems.

Project Objectives – Relay voice, video and data transmissions throughout the United States and Puerto Rico via five Earth stations using 50-foot diameter antennas.

Spacecraft Payload – The communications system consisted of 12 independent fixed-gain amplifiers, or transponders, each with 36 MHz bandwidth. Common to all transponders was a wideband receiver for translating 6 GHz received carriers to 4-GHz downlink frequencies. The system included a redundant wideband receiver. Signals were allotted to the transponders by means of two multiplexers. Each 36-MHz transponder could relay 1,200 one-way voice channels, or one Color TV picture with audio, or data at 50 mbps. The five-foot parabolic antenna was normally pointed to illuminate the 48 contiguous states. Antenna phasing provided coverage of Alaska and Puerto Rico. A separate spot beam was used for Hawaii.

Project Results – Westar 1 was launched from Kennedy Space Center, Florida on April 13, 1974. After positioning at 99 degrees west longitude over the Pacific, it entered commercial service. Westar 1 became the first United States domestic communications satellite. The Westar system transmitted voice, data and video throughout the continental United States, Alaska, Hawaii, and Puerto Rico. The system, owned and operated by Western Union, included Earth stations near New York, Atlanta, Chicago, Dallas and Los Angeles.

Westar 2 was launched October 10, 1974, positioned at 90° west longitude, and entered commercial service.

Major Participants – System owner and operator, Western Union Telegraph; spacecraft prime contractor, Hughes Aircraft Co.; Earth station constructor, Burns and Roe, Inc.; Earth station electronics, ITT; launch vehicle prime contractor, McDonnell Douglas Astronautics Co.; launch operations, NASA Kennedy Space Center.

Key Spacecraft Personnel	Affiliation
PM R.J. Goss	NASA-GSFC

SYNCHRONOUS METEOROLICAL SATELLITE-A (SMS-1)

Launch Vehicle – Straight-Eight Delta. First stage thrust was 205,000 pounds. Carried nine strap-on solid propellant motors on first stage. Each Castor II solid generated 52,000 pounds of thrust. The second stage produced 9,800 pounds of thrust and was capable of restarting. It used a modified version of the Apollo Lunar Module Descent Engine developed by TRW for the moon-landing program. The third stage used a Thiokol solid motor that generated 14,100 pounds of thrust.

Spacecraft Description – Cylindrical body, 75 inches in diameter, 103 inches tall, including magnetometer. Weight at launch was 1,385 pounds. Weight decreased to 630 pounds in orbit after apogee boost motor was jettisoned. Spacecraft was spin stabilized, rotating at 100 rpm. Power was provided by 15,000 solar cells on six solar panels on the exterior of the drum and two 20-cell nickel-cadmium batteries.

Project Objectives – First weather observer designed to operate in a fixed position above the equator in geosynchronous orbit; able to distinguish between clouds 1.2 miles wide in visible light, 5.8 miles wide in infrared light. Collected weather data from 10,000 automatic ground stations in six hours.

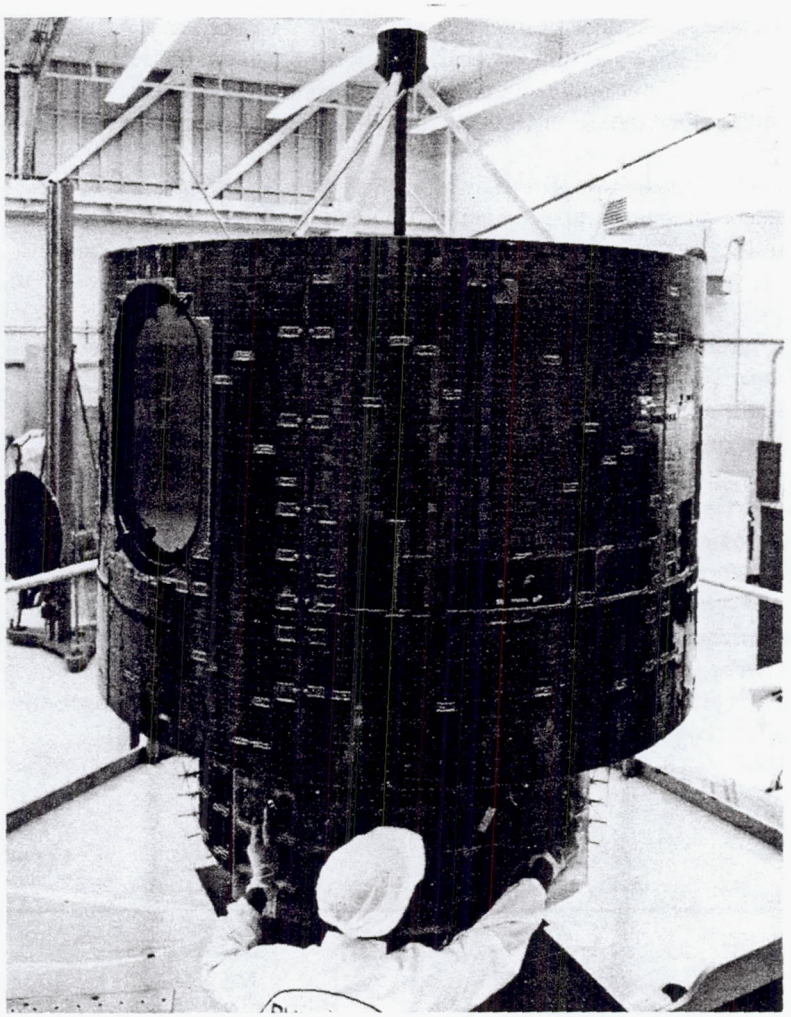
Spacecraft Payload – Weather camera – called a visible/infrared spin-scan radiometer; communications system to relay data from ground stations back to central collection point; space environment monitoring system to measure solar flare activity.

Project Results – SMS-1 was launched from Kennedy Space Center May 17, 1974 aboard a Delta "Straight-Eight" launch vehicle. Initial orbit was 35,788 mile apogee, 35,785-mile perigee. At second apogee, a small solid-rocket motor was fired to circularize the orbit at 22,300 miles. It was positioned over the equator at 45 degrees west longitude. Initially the spacecraft was used to gather data in connection with the Global Atmospheric Research Program. It was the first weather observer designed to operate in a fixed geosynchronous orbit above the equator.

Major Participants – Spacecraft management by NASA's Goddard Space Flight Center for the National Oceanic and Atmospheric Administration. Spacecraft prime contractor, Philco-Ford Corp. Launch vehicle management by NASA's Lewis Research Center. Prime contractor was McDonnell Douglas Corp.

Key Spacecraft Personnel	Affiliation
PM D. Fordyce	NOAA-NESS
PS W.E. Shenk	NASA-GSFC

Experiment	Experiment Personnel	Affiliation
Spin-Scan Radiometer	PI Ness Staff	NOAA-NESS
	OI W.E. Shenk	NASA-GSFC
Solar Energetic Particles	PI D.J. Williams	NOAA-ERL
	OI H.H. Sauer	NOAA-ERL
Solar X-Ray Monitor	PI D.J. Williams	NOAA-ERL
	OI R.F. Donnelly	NOAA-ERL
Bi-Axis Fluxgate	PI D.J. Williams	NOAA-ERL
Magnetometer	OI J.N. Barfield	NOAA-ERL
Meteorological Data	CO J. Puerner	NOAA-NESS
Collection System	PI Ness Staff	NOAA-NESS
	CO R.J. Wirth	NASA-GSFC



NASA's Synchronous Meteorological Satellite (SMS-A) is prepared for final systems test prior to shipment to Cape Kennedy.

Launch Vehicle – Titan IIIC. A three-stage liquid-propellant core vehicle supplemented by two solid-rocket-motor strap-ons. The two solids generated 1.2 million pounds of thrust. The first stage developed 440,000 pounds; the second stage developed 100,000 pounds and the third stage generated 16,000 pounds.

Spacecraft Description – ATS-6 was the most complex and powerful communications system in the 15-year history of communications satellites. It weighed 3,090 pounds and was 26 feet high. It consisted of an Earth-viewing module housing controls and Earth-viewing experiments. The EVM was attached to a 30-foot-diameter deployable reflector antenna by a tubular support truss. Two structural arms, each supporting a semi-cylindrical solar array, extended from a hub that supported the reflector. Earth-viewing module was built in three separate sections. The bottom section was the experiments module that housed antennas and experiments that required an Earth-pointing orientation. The center section, the service module, contained attitude control, propulsion, telemetry and command, and parts of the power supply subsystems. The upper section, the communications module, housed the transponder. Antenna feeds that radiated energy from the transponder to the nine-meter reflector for relay to Earth were located on top of the communications module. The EVM weighed 2,000 pounds, was 54 by 54 inches on the sides and was 63 inches high. The reflector support truss that connected EVM to the 30-foot antenna was made of graphite-reinforced plastic. The truss was 13 feet high and 54 inches square. The deployable reflector consisted of a five-foot aluminum hub from which protruded 48 aluminum ribs. The ribs were covered with a flexible mesh of copper-coated dacron covered with silicon. The antenna weighed 180 pounds.

Project Objectives – To serve an international community as a special broadcasting station in space. It tested a variety of new space communications concepts requiring geosynchronous orbit. These included broadcast of health and education television to small, low-cost ground stations in remote regions; aeronautical and maritime communications, position-location and traffic-control techniques, and spacecraft tracking and data relay.

Spacecraft Payload – Carried more than 20 technology and science experiments: Health-Education Telecommunications Experiment; Appalachian Educational Satellite Project; Satellite Technology Demonstration of the Federation of Rocky Mountain States; Alaska Education Telecommunications Experiment; Veterans Administration Exchange of Medical Information Program; Satellite Instructional Television Experiment; L-Band Experiment; Tracking and Data Relay Experiment (using Nimbus F); Satellite to Satellite Experiment (using GEOS-C); all used the spacecraft radios. Very-High-Resolution Radiometer; Millimeter Wave Propagation; COMSAT Propagation Experiment; Cesium Bombardment Ion Engine Experiment; Advanced Thermal Control Flight Experiment; Spacecraft Attitude Precision Pointing and Slewing Adaptive Control Experiment; Radio Beacon Experiment; Environmental Measurements Experiment; Low-Energy Proton-Electron Experiment; Low-Energy Protons Experiment; Solar Cosmic Ray

Experiment; Auroral Particles Experiment; Particle Acceleration Measurement Experiment; Magnetometer; Omnidirectional Spectrometer; Solar Cell Radiation Damage Experiment; International Magnetospheric Relay Equipment; Spacecraft Vibration Accelerometer; Quartz Crystal Contamination Monitor; Television Camera; Interferometer High-Data–Rate Acquisition System.

Project Results – ATS-6 was launched from NASA's Kennedy Space Center on May 30, 1974, into geosynchronous orbit. Its initial operating station was at 94 degrees west longitude above the equator. Plans called for movement about a year after launch to 35 degrees east longitude over Lake Victoria in Kenya. Initial parking orbit was 95 by 541 miles. At first northern crossing of the equator a short burst from the third stage put the spacecarft into transfer orbit with apogee of 35,820 miles. At apogee, the third stage was reignited and the spacecraft was placed in a circular, geosynchronous orbit.

Major Participants – Program management by NASA's Goddard Space Flight Center; Prime contractor, Fairchild Industries. Launch vehicle management by the U.S. Air Force Space and Missile Systems Organization. Prime contractor, Martin Marietta Corp.

Key Spacecraft Personnel		Affiliation
PM	J.M. Thole - Launch	NASA-GSFC
PM	H. Gerwin - Phase A-B	NASA-GSFC
PM	A. Sabelhouse	NASA-GSFC
PM	J. Kupperian - Operations	NASA-GSFC
PM	C. MacKenzie - Extended Operations	NASA-GSFC
PS	E.A. Wolff	NASA-GSFC
MG	W.M. Lew, Jr.	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Low Energy Protons	OI	A. Konradi	NASA-JSC
	PI	T.A. Fritz	NOAA-ERL
	OI	D.J. Williams	NOAA-ERL
Magnetometer Tri-Axis Fluxgate	PI	P.J. Coleman, Jr.	University of California, Los Angeles
	OI	W.D. Cummings	Gambling College
Low Energy Proton-Electron	PI	R.L. Arnoldy	University of New Hampshire
Particles Accelerator Measurement	PI	J.R. Winckler	University of Minnesota
	OI	G.K. Parks	University of Washington
Auroral Particles Experiment	PI	C.E. McIlwain	University of California, San Diego
	OI	R.W. Fillius	University of California, San Diego
Solar Cosmic-Ray Experiment	PI	A.J. Masley	TRW Systems Group
	OI	P.R. Satterblom	McDonnell-Douglas Corporation
Omnidirectional Spectrometer	PI	G.A. Paulikas	Aerospace Corporation
	OI	J.B. Blake	Aerospace Corporation

Very High Resolution Radiometer	PI	W.E. Shenk	NASA-GSFC
	OI	A.W. McCulloch	NASA-GSFC
	OI	I.L. Goldberg	NASA-GSFC
Radio Beacon	PI	K. Davies	NOAA-ERL
	OI	R.B. Fritz	NOAA-ERL
	OI	R.N. Grubb	NOAA-ERL
RF Interference	CO	V. Palazzola	Hughes Aircraft Company
	PI	V.F. Henry	NASA-GSFC
MM Wave Propagation	PI	L.J. Ippolito	NASA-GSFC
Cesium Ion Engine	PI	R.O. Bartlett	NASA-GSFC
Solar Cell Damage	PI	W. Dunkerly	Hughes Aircraft Company
Sat. Instrument Television Experiment	PI	J.E. Miller	NASA-GSFC
Data Relay Satellite System	PI	I.Y. Galicinao	NASA-GSFC
Position, Locator, Aircraft, Communications	PI	I.Y. Galicinao	NASA-GSFC
	OI	A.F. Ghais	Communications Satellite Corporation
Spacecraft Attitude Control	PI	W.C. Isley	NASA-GSFC
Propagation Experiment	PI	G. Hyde	Communications Satellite Corporation
Adv. Thermal Flight Experiment	PI	J. Kirkpatrick	NASA-ARC
Quartz Crystal Microbalance	PI	J.F. Rogers	NASA-GSFC
Health Education Telecom.	PI	A.A. Whalen	NASA-GSFC
TV Relay-Small Terminals	PI	J.E. Miller	NASA-GSFC
RF Interferometer Subsystems	PI	A. Kampinsky	NASA-GSFC
Vibration Accelerometer	PI	R.A. Mattson	NASA-GSFC
Television Camera	PI	G.C. Patterson	NASA-GSFC

HAWKEYE SCIENTIFIC SATELLITE (EXPLORER 52)

Launch Vehicle – Five-stage Scout-E that incorporated a BE-3A solid rocket motor into the fifth stage. It was fitted with an attitude correction system required to orient the fourth and fifth stages in the proper pitch plane before fifth-stage ignition.

Spacecraft Description – Hawkeye was an eight-sided truncated cone with a base diameter of 30 inches, top diameter of 10 inches, 30-inch height. It weighed 58.7 pounds. The spacecraft structure provided mounting surfaces to support electronic and mechanical packages for experiments. Solar cell panels were mounted on all sides and bottom. Several sensors and booms projected from the spacecraft to support experiments: two electric field antenna booms extended to 75 feet; a fluxgate magnetometer boom and a search coil magnetic antenna were extendable to five feet.

Project Objectives – Hawkeye's primary objective was to investigate the interaction of the solar wind with the Earth's magnetic field, with emphasis on the north polar cap. Secondary objectives included locating magnetic neutral points or lines during both quiet and disturbed solar wind conditions, and studying the magnetic field topology at large radial distances over the planet's polar caps.

Spacecraft Payload – Three instruments, all provided by the University of Iowa. There was a flux-gate magnetometer, a low-energy proton-electron differential energy analyzer, and a VLF-ELF electric and magnetic-field receiver.

Project Results – Hawkeye was launched June 3, 1974 from the Air Force Western Test Range at Vandenberg AFB, Calif. Its orbit was "considerably more elliptical than planned, but something we can live with," project officials said. Inclination was 90 degrees, as planned. Apogee was 125,274 miles (63,390 planned). Perigee was 2,145 miles (310 planned).

Major Participants – Program management by NASA's Langley Research Center. The spacecraft was designed and built by the University of Iowa. Vought Systems Div., LTV Aerospace Corp., built the launch vehicle for Langley Research Center. Launch services were provided by LTV's Vought Division under technical direction of USAF 6595th STG and Kennedy Space Center's Unmanned Launch Operations.

Key Spacecraft Personnel	Affiliation
PM J.E. Rogers	University of Iowa
PS J.A. Van Allen	University of Iowa
SC E.R. Schmerling	NASA Headquarters
MG J.R. Holtz	NASA Headquarters
PM C.W. Coffee, Jr.	NASA-LARC

Experiment	Experiment Personnel	Affiliation
Magnetometer	PI J.A. Van Allen	University of Iowa
	OI L.J. Cahill, Jr.	University of Minnesota
Lepedea	PI L.A. Frank	University of Iowa
	OI J.D. Craven	University of Iowa
	OI D.M. Yeager	University of Iowa
ELF-VLF	PI D.A. Gurnett	University of Iowa
	OI G.W. Pfeiffer	University of Iowa

AEROS -A - B

Launch Vehicle – Solid propellant Scout: 101,000-pound thrust Algol II first stage, 61,000-pound thrust Castor II second stage, 21,000-pound thrust Antares II third stage, and an Altair III fourth stage. Height: 73 feet. Vehicle weight at liftoff: 40,000 pounds.

Spacecraft Description – A cylinder 36 inches in diameter, 28 inches high with a conical shell at one end from which a 71-inch probe extended. The flat end was covered with solar cells. These provided power to a nickel-cadmium battery. Power requirements varied from 4.7 watts to 34.3 watts. The spacecraft weighed 280 pounds and the payload weighed 62 pounds.

Project Objectives — Measurement of the Earth's upper atmosphere, continuing studies of Aeros-A, launched December 16, 1972

Spacecraft Payload – Five experiments, four German and one American. The German experiments were a mass spectrometer to study chemical composition of atmosphere and ionosphere; a retarding potential analyzer to determine electron energy distribution and ion temperature; an impedance probe to measure electron density; an extreme ultraviolet spectrometer to measure intensity of solar radiation. The U.S. experiment, operated by NASA's Goddard Space Flight Center measured temperatures and over-all density of the upper atmosphere.

Project Results — The German-built and operated spacecraft was launched July 16, 1974 from Vandenberg Air Force Base, California. Its initial orbit was 211 km perigee, 555 km apogee, 97.44 degrees inclination and 92.1 minute period. This was different from the planned orbit (230 km perigee, 560-mile apogee, 96.8-degree inclination and 96-minute period). Officials said, however, that the orbit was "acceptable."

An earlier satellite in this series, AEROS-A was launched from the Western Test Range on December 16, 1972.

Major Participants – Cooperative project between the Bundesministerium for Foschung and Technologie of the Federal Republic of Germany and NASA. Project management for the U.S. space agency was Goddard Space Flight Center. Launch vehicle managed by Langely Research Center. Prime contractor was LTV Aerospace's Vought Division. Launch operations were conducted by the U.S. A.F. 6595 STG at Vandenberg AFB.

Key Spacecraft Personnel		Affiliation
PS	P. Laemmerzahl	MPI-Nuclear Physics
PS	S.J. Bauer	NASA-GSFC
PM	C.L. Wagner, Jr.	NASA-GSFC
PM	H. Schreiber	Gesellschaft Fur Weltraumforschung
SC	E.R. Schmerling	NASA Headquarters
MG	J.R. Holtz	NASA Headquarters
MG	M. Otterbein	BM BW, Germany

Key Spacecraft Personnel		Affiliation
PS	P. Laemmerzahl	MPI-Nuclear Physics
PS	S.J. Bauer	NASA-GSFC
PM	C.L. Wagner, Jr.	NASA-GSFC
PM	N. Kiehne	Gesellschaft Fur Weltraumforschung
SC	E.R. Schmerling	NASA Headquarters
MG	J.R. Holtz	NASA Headquarters
MG	M. Otterbein	BM BW, Germany

Experiment	Experiment Personnel		Affiliation
Mass Spectrometer	PI	D.K.H. Krankowsky	MPI-Nuclear Physics
	OI	P. Laemmerzahl	MPI-Nuclear Physics
Retarding Pot Analyzer	PI	K. Spenner	Institut fur Physik und Weltraum-forschung
	OI	A. Dumbs	Institut fur Physik und Weltraum-forschung
Impedance Probe	PI	E. Neske	Institut fur Physik und Weltraum-forschung
	OI	R. Kist	Institut fur Physik und Weltraum-forschung
EUV Spectrometer	PI	G. Schmidtke	Institut fur Physik und Weltraum-forschung
	OI	W. Schweizer	Institut fur Physik und Weltraum-forschung
Neutral Atmosphere Temperature	PI	N.W. Spencer	NASA-GSFC
	OI	D.T. Pelz	NASA-GSFC
	OI	G.P. Newton	NASA-GSFC
	OI	G.R. Carignan	University of Michigan
	OI	H.B. Niemann	NASA-GSFC
Atmospheric Drag Analysis	PI	M. Roemer	University of Bonn
	OI	C. Wulf-Mathies	University of Bonn

ASTRONOMICAL NETHERLANDS SATELLITE (ANS)

Launch Vehicle – Four-stage Scout.

Spacecraft Description – The 265-pound (129 kg) spacecraft was in the shape of an eight-sided prism 45.27 inches high, 29 inches deep and 23.6 inches wide. The basic structure was a set of aluminum honeycomb sandwich sheets in double-bar H shape. Two solar panels, containing 1,980 solar cells, provided continuous power supply of 35 watts to run the spacecraft, the three experiments, and to charge the on-board battery. The spacecraft was three-axis stabilized, the first launched aboard a Scout to be so stabilized.

Project Objectives – To seek information that could provide a better understanding of the anatomy of stars, galaxies and the universe itself by studying the sky in ultraviolet and x-ray wavelengths from above the atmosphere.

Spacecraft Payload – Two instruments were provided by the Netherlands: an 8.66-inch cassegrain telescope with a spectrometer and five ultraviolet-sensitive photomultipliers that cover the range from 1,500 to 3,000 angstroms; and a two-detector soft x-ray experiment that covers the range from 0.3 to 5 KeV. The third experiment was provided by the United States, a large-area detector to study x-rays in the 2 to 15 keV range and a Bragg crystal spectrometer to obtain silicon x-ray line emissions around 2 keV. The payload weighed 84 pounds.

Project Results – Launched from Western Test Range on Aug. 30, 1974, into a Sun-synchronous orbit 1,098 by 256 miles, an inclination of 98.0 degrees and a 98.2-minute period.

Major Participants – Netherlands Agency for Aerospace Programs was responsible for that country's project management. NASA's Goddard Space Flight Center had U.S. management responsibility. The spacecraft was built by the Industrial Consortium Astronomical Netherlands Satellite. The U.S. experiment was built by American Science & Engineering, Inc. LTV Aerospace built the Scout launch vehicle for NASA's Langley Research Center. Command, control and data acquisition were accomplished at the ESA ground station at Darmstadt, Germany.

Key Spacecraft Personnel		Affiliation
PM	W. Bloemendal	Fokker Aircraft Company
PM	E.W. Hymowitz	NASA-GSFC
CO	G.E. Kowalski	NASA-GSFC
SC	N.G. Roman	NASA Headquarters
PS	T.P. Stecher	NASA-GSFC
MG	J.R. Holtz	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
1500-3300A Ultraviolet Experiment	PI	R.J. Vanduinen	University of Groningen
	OI	J. Borgman	University of Groningen
Soft (.2-4 keV) X-Ray Experiment	PI	A.C. Brinkman	University of Utrecht
Hard (2-40 keV) X-Ray Experiment	PI	H. Gursky	Harvard College Observatory
	OI	H.W. Schnopper	Massachusetts Institute of Technology

UK-5 (Ariel 5)

Launch Vehicle – Scout.

Spacecraft Description – Cylindrical shape, 28 inches long by 29.5 inches diameter. It weighed 284 pounds, and carried six experiments. Data were stored on board and transmitted to ground stations once each orbit.

Project Objectives – To measure the spectrum, polarization and pulsar features of non-solar x-ray sources.

Spacecraft Payload – Six experiments: (1) 0.3-30 keV cosmic x-rays with rotation collimator; (2) 2-10 keV sky survey; (3) high-resolution source spectra; (4) polarimeter/spectrometer; (5) high-energy cosmic x-ray spectra; (6) all-sky monitor.

Project Results – Ariel 5 was launched from the San Marco launch platform in the Indian Ocean on October 15, 1974 into an orbit whose apogee is 557 miles, perigee 513 miles, and inclination of 2.86 degrees.

Major Participants – The spacecraft was built by Appleton Laboratories, Slough, England. Management for NASA was by Goddard Space Flight Center. The Science Research Council managed the project for the U.K. The Scout launch vehicle was built by LTV Aerospace for NASA's Langley Research Center.

Key Spacecraft Personnel		Affiliation
PM	J.P. Corrigan	NASA-GSFC
PS	S.S. Holt	NASA-GSFC
MG	J.R. Holtz	NASA Headquarters
SC	N.G. Roman	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
0.3-30 keV X-Ray Rot. Collim.	PI	R.L.F. Boyd	University College London
	OI	A.P. Willmore	University of Birmingham
	OI	P.W. Sanford	University College London
2-10 keV Sky Survey	PI	K.A. Pounds	University of Leicester
	OI	B.A. Cooke	University of Leicester
	OI	D.J. Adams	University of Leicester
	OI	R.E. Griffiths	University of Leicester

High Resolution Prop Center Stellar Spectrum	PI	R.L.F. Boyd	University College London
	OI	A.P. Willmore	University of Birmingham
	OI	P.W. Sanford	University College London
Stellar X-Ray Polarimeter Spectrometer	PI	K.A. Pounds	University of Leicester
	OI	B.A. Cooke	University of Leicester
	OI	D.J. Adams	University of Leicester
	OI	R.E. Griffiths	University of Leicester
Pointed High Energy Experiment	PI	H. Elliot	Imperial College
	OI	J.J. Quenby	Imperial College
	OI	A.R. Engel	Imperial College
3-6 keV All Sky Monitor	PI	S.S. Holt	NASA-GSFC
	OI	E.A. Boldt	NASA-GSFC
	OI	P.J. Serlemitsos	NASA-GSFC

ITOS G(NOAA 4)/ OSCAR 7/INTASAT

Launch Vehicle – Two-stage Delta, model 2310, with liftoff thrust of 286,500 pounds.

Spacecraft Description – ITOS box-shaped main body, 40 X 40 X 49 inches, with three solar panels attached to one end of the structure. Momentum flywheel provided spacecraft stabilization. ITOS G weighed about 750 pounds.

INTASAT – Twelve-sided polyhedron covered with solar arrays. Masts protruded at 90-degree intervals from the base of the structure, and from the top and bottom of the spacecraft. Weight at launch was approximately 45 pounds.

OSCAR 7 – Octahedral main structure covered with solar arrays. Four radio masts protruded from base of structure at 90-degree intervals. The spacecraft weighed 63 pounds.

Project Objectives – The National Oceanic and Atmospheric Administration managed and operated the basic U.S. weather satellites, called NOAA's in orbit, which provided daily cloud-cover pictures and other information for worldwide weather forecasting. Development of the series began in the late 1950's. From 1960 to 1965, the satellites were called TIROS, for Television InfraRed Observation Satellite. Ten of these were orbited. From 1966, when the satellites were declared operational, to 1969, they were known as TOS, for TIROS Operational Satellite, or as ESSA, for the Environmental Science Services Administration, which managed the program in that period. Nine were orbited. In 1970, a second generation satellite, known as ITOS, for Improved TOS, was introduced. Later the satellites were given an ITOS letter designation before launch and a NOAA number designation in orbit.

ITOS provided images, atmospheric temperature and moisture data, solar proton count information, and other data for use in providing day and night weather coverage of the entire Earth from space.

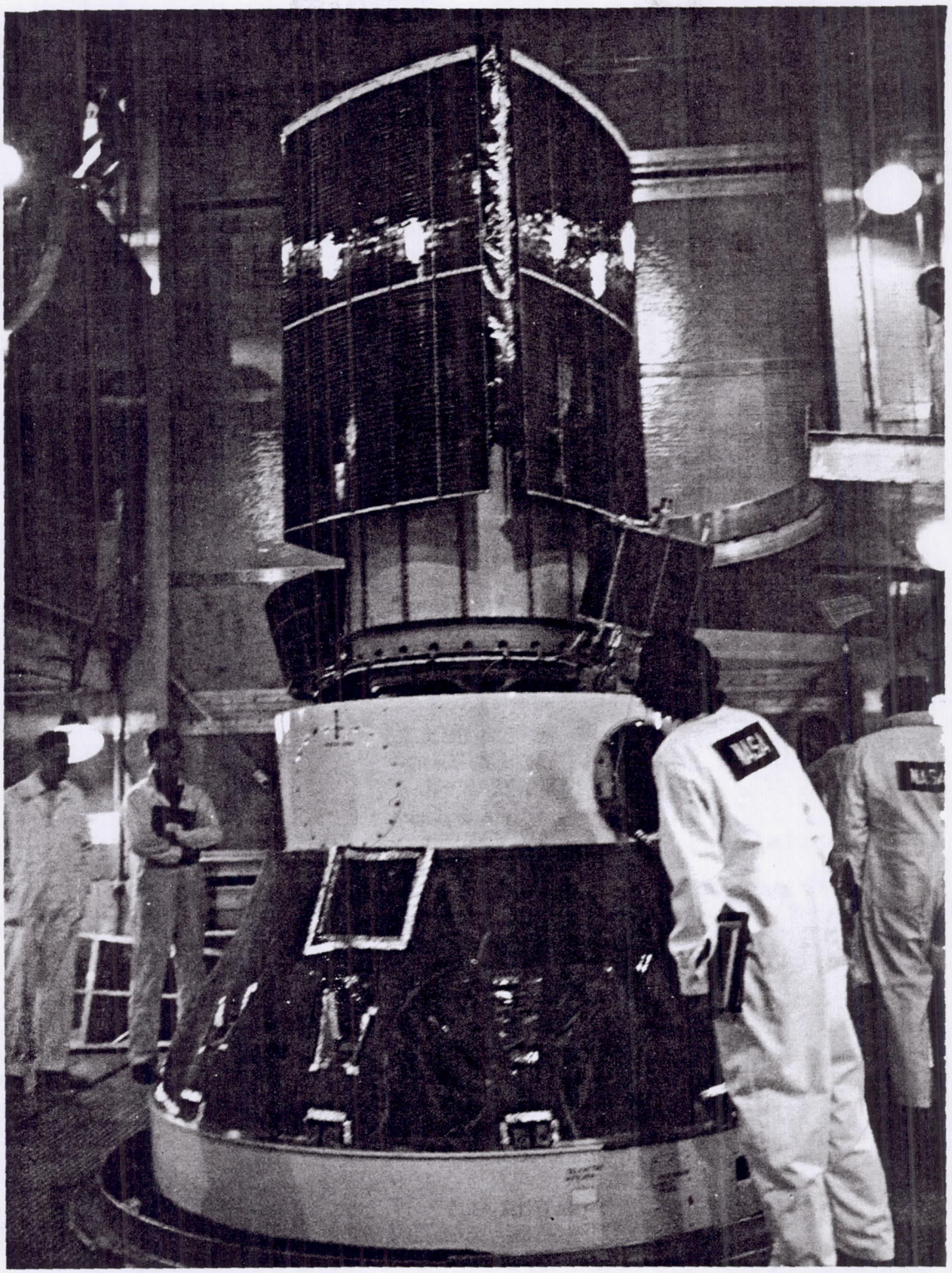
INTASAT – Conducted worldwide observations of ionospheric total electron counts, ionospheric irregularities, and ionospheric scintillation.

OSCAR 7 – Provided communications for amateur radio enthusiasts around the world, with emphasis on transmission of educational broadcasts to schools.

Spacecraft Payload –

ITOS – Scanning radiometer system in visible and infrared channels; very high resolution radiometer, with resolution of 1/2 mile (scanning radiometer resolution is 2 to 4 miles); vertical temperature profile radiometer; solar proton monitor.

INTASAT – Beacon transmitter for ionospheric experimentation and an experiment package to monitor radiation effects on C/MOS devices.



A three-in-one launch. Delta 104 launched simultaneously, ITOS-G/NOAA-4 weather satellite, INTASAT Spanish scientific satellite, and AMSAT-Oscar-7, designed to serve radio amateur communcations.

1974

C-7

OSCAR 7 – Two experimental repeater systems for communication; a store-and-forward message storage unit.

Project Results – The three satellites were launched from Vandenberg AFB, California on November 15, 1974 into their intended orbits.

Major Participants – ITOS and Delta project management, NASA Goddard Space Flight Center, ITOS prime contractor, RCA; Intasat was managed by the Spanish Government's Institutio Nacional De Technica Aerospacial (INTO); OSCAR 7 was built by a multinational team of radio "hams" under the direction of the Radio Amateur Satellite Corporation (AMSAT); launch service, NASA, Unmanned Launch Operations; launch vehicle prime contractor, McDonnell Douglas Astronautics Co.

Key Spacecraft Personnel		Affiliation
ITOS G (NOAA 4)		
PM	G.A. Branchflower	NASA-GSFC
PS	I.L. Goldberg	NASA-GSFC
CO	C.M. Hunter	NASA-GSFC
PM	A. Butera	NOAA-NESS
MG	M.L. Garbacz	NASA Headquarters
INTASAT/OSCAR 7		
PS	G. Sagredo	Conie-Inta
PS	L.H. Brace	NASA-GSFC
PM	J.M. Dorado	Conie-Inta
MG	J.R. Holtz	NASA Headquarters
SC	E.R. Schmerling	NASA Headquarters
PM	W.R. Witt, Jr.	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
ITOS G (NOAA 4)			
Solar Proton Monitor	PI	D.J. Williams	NOAA-ERL
	OI	H.H. Sauer	NOAA-ERL
Scanning Radiometer	PI	Ness Staff	NOAA-NESS
Very High Resolution Radiometer	PI	Ness Staff	NOAA-NESS
Vertical Temperature Prfl. Radiometer	PI	Ness Staff	NOAA-NESS
INTASAT/OSCAR 7			
Ionospheric Beacon	PI	J.L. Sagredo	Conie-Inta

INTELSAT IV-F-8

Launch Vehicle – Atlas-Centaur: Atlas booster developed 430,000 pounds with two 185,000 main engines and one 60,000-pound sustainer. Centaur stage's two engines developed 15,000 each. A new Centaur guidance and electronic system featuring a new, onboard high-speed digital computer was introduced in 1973. Vehicle was 132 feet high.

Spacecraft Description – Drum-shaped; 17 feet high, eight-feet in diameter. Weight at launch, about 3,100 pounds. Weight in orbit, about 1,500 pounds. Drum covered with 45,000 solar cells providing approximately 570 watts of power. Solid propellant SVM-4A apogee kick motor mounted on spacecraft developed 10,000 pounds thrust.

Project Objectives – Fourth-generation satellite to increase capacity of Intelsat's global communications network. Each Intelsat IV carried 5,000 to 6,000 two-way telephone calls or 12 channels of color TV.

Spacecraft Payload – The communications subsystem was mounted on a mechanically despun platform and included six antennas: two 50-inch dishes for spotbeam transmission to Earth and a cluster of four conical horn antennas – two for wideband transmission to Earth, two for reception from Earth. Antennas were connected to a 12-channel microwave repeater system that provided power amplification of each channel individually. Each 50-inch dish could be directed to any spot on Earth within the spacecraft's line of sight.

Project Results – Background: The International Telecommunications Satellite (INTELSAT) Consortium comprised a partnership of some 85 nations formed to establish a global commercial communication satellite system. The U.S. participant in INTELSAT was the Communications Satellite (COMSAT) Corporation, which acted as manager on behalf of the consortium. The space segment of the system was owned by INTELSAT, and the ground stations were owned by public or private organizations in the countries where located. NASA launched the satellites and was reimbursed for launch service costs. The Intelsat 4 program included six satellites over the Atlantic, Pacific and Indian Oceans.) Flight 8 was launched from Cape Canaveral, Florida on November 21, 1974, into a synchronous orbit. The satellite was placed in service over the Pacific at 174 degrees east longitude.

Major Participants – Spacecraft management, COMSAT Corp. for Intelsat consortium; Spacecraft prime contractor, Hughes Aircraft Co.; Launch vehicle management, NASA Lewis Research Center; Launch vehicle prime contractor, General Dynamics/Convair; Apogee motor, Aerojet-General; Major suppliers from 10 countries made up the international contractor team.

SKYNET IIA and IIB

Launch Vehicle – Delta "straight eight" model 2313.

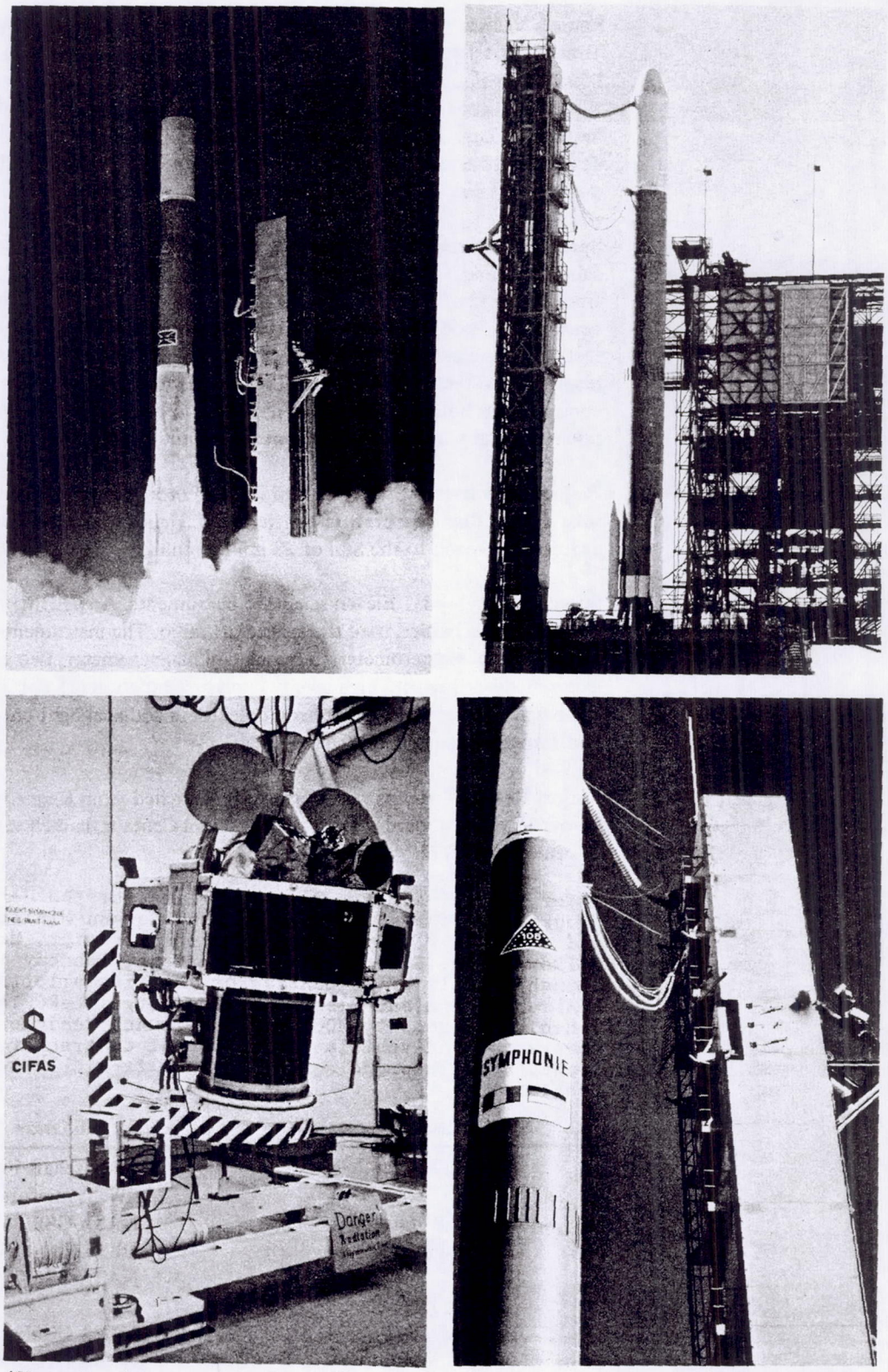
Spacecraft Description – Cylindrical main structure 75 inches in diameter. Height, including antenna, 82 inches. Spacecraft was spin-stabilized at 90 rpm, with mechanically despun conical antenna atop the cylinder. Onboard apogee kick motor was mounted in main body. Solar arrays covering the cylinder provided 200 watts of power. Weight: 959 pounds at launch, 517 pounds in orbit.

Project Objectives – Provide military communications via satellite throughout the United Kingdom.

Spacecraft Payload – X-band repeater system with two channels, one 20 MHz, the other 2 MHz. The system included a pair of redundant 16-watt traveling wave tube amplifiers. Telemetry system operated in S-band.

Project Results – Skynet IIA was launched January 18, 1974 from Cape Canaveral. It did not achieve its intended orbit due to a failure in the launch vehicle's second stage electronics. Skynet IIB was launched from Cape Canaveral November 22, 1974, and was in service at synchronous orbit over the Indian Ocean. Skynet was the United Kingdom's military communications satellite program. The satellites and associated ground equipment provided the UK with secure communications between the British Isles and their Middle and Far East forces. The system operated with both land-based and shipboard terminals. Skynet II was a second-generation satellite intended to provide higher power, allowing the addition of small transportable ground stations to the network.

Major Participants – Spacecraft management, UK Ministry of Defence; spacecraft prime contractor, Marconi Space & Defence Systems, England; Spacecraft technical direction, Philco-Ford Western Development Laboratories; launch operations, NASA Unmanned Launch Operations, Kennedy Space Center; launch vehicle management, NASA Goddard Space Flight Center; launch vehicle prime contractor, McDonnell Douglas Astronautics Co.



(Upper Row) On November 22, 1974 another satellite in the Skynet series was successfully orbited supporting British military communications. (Lower Row) Serving both French and German communications, Symphonie-A was launched on December 17, 1974. The satellite linked Europe, Africa, and South America.

HELIOS-A

Launch Vehicle – Titan-Centaur – Combined Centaur upper stage with the Titan III booster. Centaur was the nation's first high-energy liquid hydrogen-liquid oxygen rocket. It developed 133,440 newtons (30,000 pounds) of thrust at altitude. The Titan was a two-stage liquid propellant core rocket having two large 120-inch diameter strap-on solid rocket motors which developed 10.6 million newtons (2.4 million pounds) thrust at liftoff. This was the first successful operational flight of the Titan Centaur rocket.

Spacecraft Description – Main body was a central 5.7-foot diameter, 16-sided experiment compartment, 1.8 feet high. Conical solar arrays extended from each end of the compartment, giving the spacecraft its spool-shaped appearance. Spool height was 7 feet; an antenna mast added another 6.7 feet to the vehicle's height. Two magnetometer booms with a tip-to-tip length of 105 feet deployed from the sides of the main body. The central compartment housed 11 experiments with a combined weight of 158 pounds. Total spacecraft weight was 815 pounds in orbit.

Project Objectives – Study the Sun from an orbit nearer the center of the solar system than any previously attempted. Helios was intended to make a closest approach to the Sun of 28 million miles.

Spacecraft Payload – Eleven scientific instruments. A twelfth experiment, in celestial mechanics, used the spacecraft radio. The instruments include two flux-gate magnetometers; a search coil magnetometer; two cosmic ray experiments at low and high energy; a plasma experiment; a plasma and radio wave experiment; an electron detector; a zodiacal light photometer; and a micrometeoroid analyzer.

Project Results – Helios was successfully launched from Kennedy Space Center, Florida, aboard a Titan IIIE, or Titan-Centaur, launch vehicle, on December 10, 1974.

Major Participants — Responsibility for the Joint U.S.-German program was shared by NASA and the German Ministry for Research and Technology. Spacecraft prime contractor, Messerschmitt-Bolkow-Blohm, GmBH; launch operations, Kennedy Space Center; launch vehicle prime contractor, Martin Marietta Aerospace; USAF and Space and Missile Systems Org.; LeRC; launch vehicle management, GDC; Centaur launch vehicle prime contractor and vehicle international contractor, Titan launch vehicle prime contractor, Delta kick motor, McDonnell Douglas.

Key Spacecraft Personnel	Affiliation
PM A. Kutzer	Gesellschaft Fur Weltraumforschung
PM G.W. Ousley	NASA-GSFC
PS H. Porsche	DFVLR
PS J.H. Trainor	NASA-GSFC
CO K. Kasmeier	BWF
SC A.G. Opp	NASA Headquarters
MG E.J. Montoya	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Tri-Axis Fluxgate Magnetometer	PI	F.M. Neubauer	Braunschweig Technical University
	OI	A. Maier	Braunschweig Technical University
Tri-Axis Fluxgate Magnetometer	PI	N.F. Ness	NASA-GSFC
	OI	F. Mariani	University of Rome
	OI	L.F. Burlaga	NASA-GSFC
	OI	S.C. Cantarano	CNR, Space Plasma Laboratory
Tri-Axis Search Coil Magnetometer	PI	F.M. Neubauer	Braunschweig Technical University
	OI	G. Dehmel	Braunschweig Technical University
Coarse Wave Spectrum Analysis	PI	D.A. Gurnett	University of Iowa
	OI	P.J. Kellogg	University of Minnesota
	OI	S.J. Bauer	NASA-GSFC
	OI	R.G. Stone	NASA-GSFC
Fine Wave Spectrum Analysis	PI	D.A. Gurnett	University of Iowa
	OI	P.J. Kellogg	University of Minnesota
	OI	S.J. Bauer	NASA-GSFC
	OI	R.G. Stone	NASA-GSFC
27-kHz - 3-MHz Radio Wave	PI	D.A. Gurnett	University of Iowa
	OI	P.J. Kellogg	University of Minnesota
	OI	R.R. Weber	NASA-GSFC
	OI	R.G. Stone	NASA-GSFC
1 MeV-1 GeV Cr. Proton + Alpha	PI	H. Kunow	University of Kiel
	OI	G.H. Wibberenz	University of Kiel
	OI	G. Green	University of Kiel
	OI	M. Mueller-Mellin	University of Kiel
	OI	M. Witte	University of Kiel
	OI	H. Hempe	University of Kiel
Cosmic Ray Detectors	PI	J.H. Trainor	NASA-GSFC
	OI	E.C. Roelof	Applied Physics Laboratory
	OI	B.J. Teegarden	NASA-GSFC
	OI	F.B. McDonald	NASA-GSFC
	OI	K.G. McCracken	CSIRO
Plasma Detectors	PI	H.R. Rosenbauer	MPI-Aeronomy
	OI	H. Pellkofer	MPI-Extraterrestrial Physics
	OI	J.H. Wolfe	NASA-ARC
Electron Detector 40 keV-1 MeV	PI	E. Keppler	MPI-Aeronomy
	OI	B. Wilken	MPI-Astronomy
	OI	D.J. Williams	NOAA-ERL

Zodiacal Light Photometer	PI	C. Leinert	MPI-Astronomie
	OI	E. Pitz	MPI-Astronomie
Micrometeoroid	PI	H. Fechtig	MPI-Nuclear Physics
	OI	J. Weihrauch	MPI-Physics Astrophysics
RF Electron Fields	PI	D.A. Gurnett	University of Iowa
	OI	S.J. Bauer	NASA-GSFC
	OI	P.J. Kellogg	University of Minnesota
	OI	R.G. Stone	NASA-GSFC
Celestial Mechanics	PI	W. Kundt	University of Hamburg
	OI	W.G. Melbourne	NASA-JPL

During 1974, Mrs. Robert H. Goddard (left), widow of the American rocket pioneer, visited the NASA center named in her husband's memory. She edited Dr. Goddard's papers and became an authority on the earlier phases on the U.S. space program.



SYMPHONIE-A

Launch Vehicle – Delta 2914 – A three-stage Delta with an overall length of approximately 35 meters (116 feet) and a diameter of 2.4 meters (8 feet). The first stage was a modified Thor booster incorporating nine strap-on solid-fuel rocket motors powered by liquid oxygen and liquid hydrocarbon propellants. The second stage was powered by a liquid-fuel pressure-fed engine which was gimbal-mounted to provide pitch and yaw control through second-stage burn. The third stage was a spin-stabliized solid-propellant motor.

Spacecraft Description – Symphonie had a diameter of 1.85 m (6.06 ft.) and a height of 0.5 m (1.64 ft.) and weighed 402 kg. The apogee motor engine and nozzle, super high frequency antenna feed and reflectors, and the reception horn and solar sensors were mounted on top. The VHF antennas were on the underside. Three solar panels extended outward 2.57 m (8.3 ft.) from the spacecraft. Power was generated by the solar panels; two batteries supplied power for spacecraft housekeeping during eclipses, when transmitting equipment could not be operated.

Project Objectives – Experimental communications satellite tests for television, radio, telephone, telegraph and data transmission. The spacecraft provided the equivalent of two channels of color television transmission and eight voice channels, or 1,200 telephone circuits.

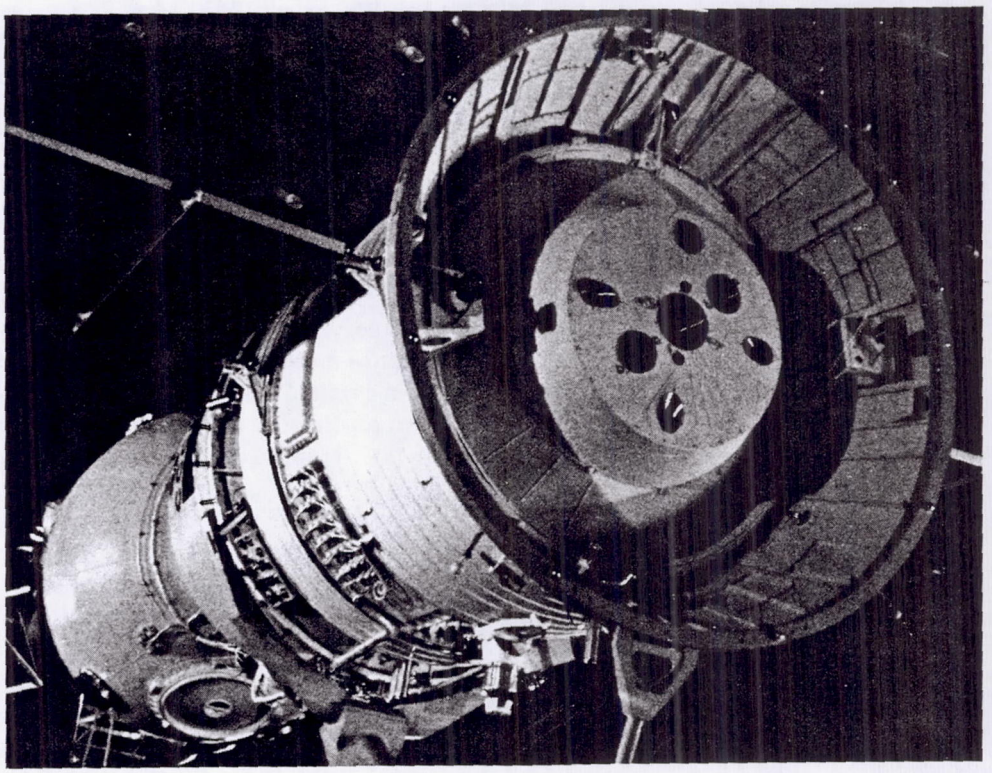
Spacecraft Payload – Super high frequency antenna and reception horn. VHF antennas.

Project Results – Symphonie was successfully launched from Cape Canaveral, Fla. on December 19, 1974 into synchronous orbit over the equator at 11.5 degrees west longitude. Symphonie was the first synchronous orbit satellite built and owned by European nations. The joint French-German communications satellite was capable of transmitting between ground stations in portions of North and South America, Europe, Africa and the Middle East.

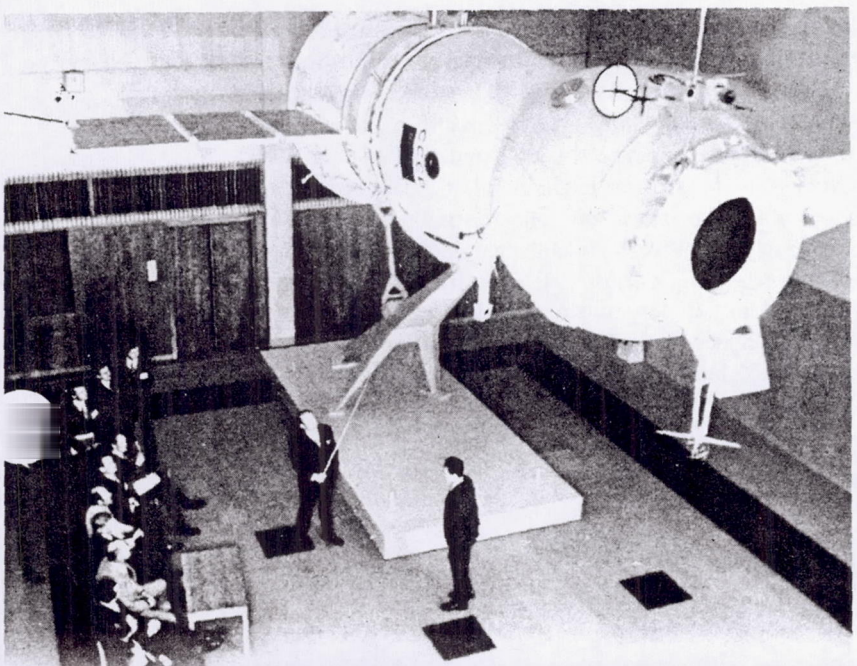
Major Participants – Spacecraft management, the Centre National d'Etudes Spatiales (CNES), and the Gesellschaft fur Weltraumforschung (GFW). Prime contractor is Consortium Industriel Franco-Allemand pour Symphonie (CIFAS), a Franco-German industrial consortium. The French firms were Société Nationale Aerospatiale, Société Anonyme de Télécommunications (S.A.T.) and Thomson-CSF. Germany's were AEG-Telefunken, Messerschmitt-BoelkowBlohm (MBB) and Siemens, A.G. Launch vehicle management, NASA Goddard Research Center. Launch vehicle prime contractor was McDonnell Douglas Astronautics Co.



1975



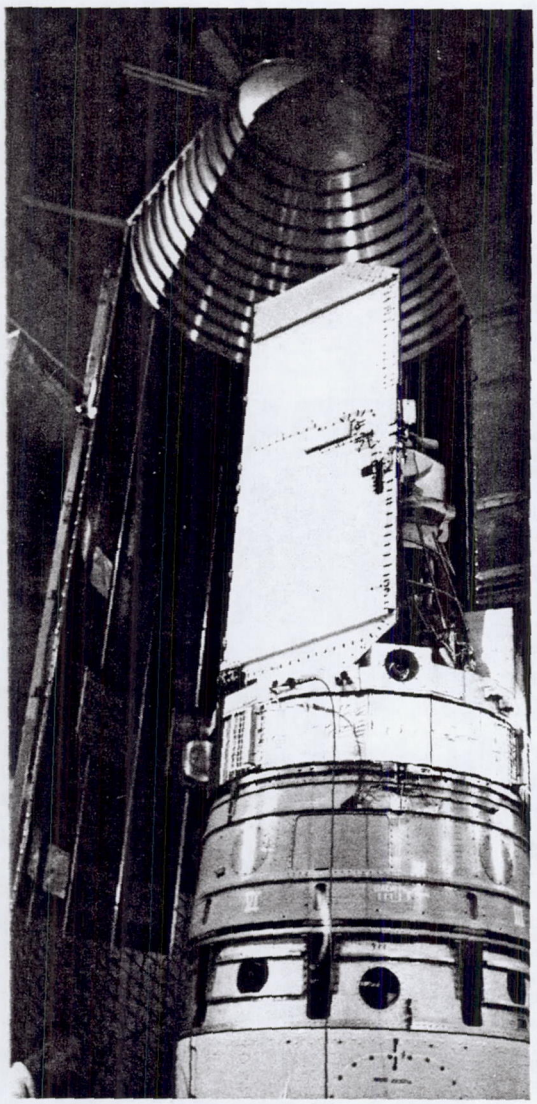
Apollo Soyuz test project provided for joint U.S./USSR space venture from July 15 to July 24, 1975. The American spacecraft docked with its Russian counterpart, Soyuz 19 on July 17, 1975.



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Briefing of NASA Apollo-Soyuz team by Russian colleagues.

LANDSAT-2



Landsat-2 during checkout. Protective shroud in background.

Launch Vehicle – Improved Delta (Delta 107) – The 116-foot (36 km) tall Delta consisted of a liquid-fuel, extended-long-tank Thor booster with nine strap-on Castor II solid-fuel rocket motors. Maximum girth of the 250,000 lb. (113,400 kg) Delta was 8-feet (2.44M) not including the strap-on motors. This was the 107th successful Delta launch with over a 90% success record.

Spacecraft Description – Design of Landsat-2 was similar to that of ERTS-1, and both were patterned after the successful Nimbus series of meteorological satellites. The Landsat-2 spacecraft consisted of integrated subsystems that provided power, thermal control, and orbit maintenance of the sensor payloads for one year in orbit. It weighed approximately 2100 pounds (953 kg) and had an overall height of 10 feet (3.04M). Landsat-2 was five feet (1.52M) in diameter, with solar paddles extending out a total of 13 feet (3.96M). Attitude of the spacecraft was controlled with a pointing accuracy of less than 0.7 degrees in roll, yaw, and pitch axes. Two wide-band video tape recorders stored up to 30 minutes each of picture information for delayed readout when the spacecraft was in view of a date acquisition station.

Project Objectives – Managing Earth's natural resources wisely and protecting its environment were among the objectives of the Earth Resources Technology Satellite (ERTS) mission. Landsat-2 was an extension of the ERTS program to aid in the assessment and understanding of environmental changes. Prime objective of Landsat-2 was acquisition of multispectral repetitive data of the surface of the Earth in the form of imagery or in digital format on magnetic tape. It was also used in developing a relay system to gather data from remote, widely distributed ground sensor platforms. Landsat-2 aided in the assessment and understanding of environmental changes in an effort to manage Earth's limited resources. Areas in which these data are applicable include: agriculture, range resources, environmental, forestry, geology, land use, marine resources, meteorology and water resources. Both U.S. and other countries used the data obtained. The U.S. Department of Agriculture, Department of Commerce (National Oceanic and Atmospheric Administration), the Army Corps of Engineers, the Environmental Protection Agency, and the Department of Interior, were to use the data in the U.S. for a wide variety of studies.

Spacecraft Payload – Landsat-2 carried the same sensors as ERTS. These include a return beam vidicon (RBV) subsystem and a multispectral scanner subsystems (MSS) sensors. The RBV and MSS provided independent images of the same 185 by 185 km (115 by 115 mi.) area of Earth in various spectral bands. A data collection system collected and relayed data from remotely located ground platforms to the Landsat-2 data acquisition stations. Up to 1,000 sensor platforms collected and relayed data to the spacecraft twice a day. Each platform collected data from as many as eight sensors, sampling such local environmental conditions as temperature, stream flow, snow depth, or soil moisture. Data via Landsat-2 were relayed to NASA's Goddard Space Flight Center, Maryland, and made available to investigators within 42 hours. A general purpose digital computer on board

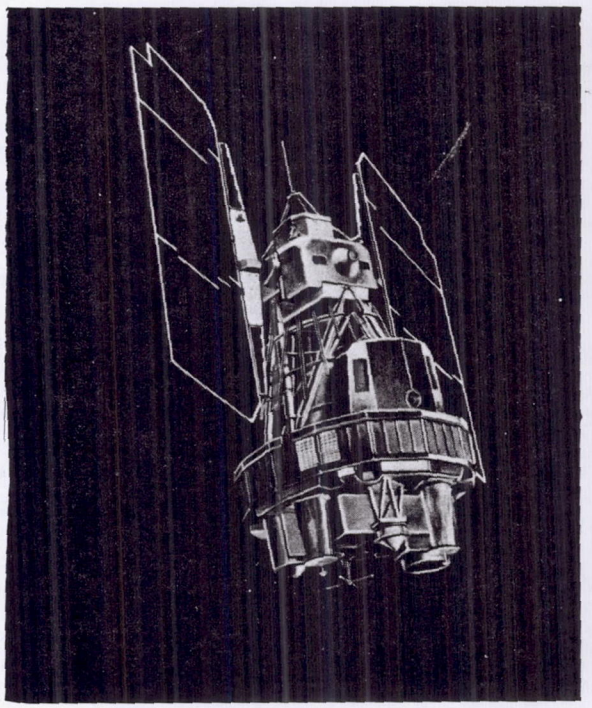
Landsat-2 could handle 55 separate commands programmed by ground stations to carry out operations on board the satellite for up to 24 hours. This unique 114-pound (30 kg) computer had a 4,096-word memory capacity to store commands. Remote, computer-directed operations were essential because Landsat-2 was out of tracking range about 80 percent of the time.

Project Results – Successfully launched on January 22, 1975 from NASA's Western Test Range at Vandenberg, California on a Delta launch vehicle, Landsat-2 operated normally returning good data for pictures.

Major Participants – Project management for the Landsat-2 spacecraft, the Delta launch vehicle, the ground data handling system, and the world-wide tracking network rested with the NASA Goddard Space Flight Center, Greenbelt, Maryland. Launching from the Western Test Range in California was supervised by the Kennedy Space Center's unmanned launch operations team. The Large Area Crop Inventory Experiment was to be managed at the Johnson Space Center, Houston, Texas.

Prime contractor for the Landsat-2 spacecraft, the data collection system aboard the spacecraft, and the ground data handling system at Goddard was the General Electric Co., Space Division. Hughes Aircraft Co., Space and Communications group was prime contractor for the multispectral scanner; and RCA, Astro-Electronics Division was prime contractor for the return beam vidicon camera. RCA, Defense Communications Division was prime contractor for the wideband video tape recorders. The McDonnell Douglas Astronautics Co. was the prime contractor for the Delta Launch vehicle.

Landsat-2, formerly Earth Resources Technology satellite, designed to help locate, map and measure Earth resources, was launched on January 22, 1975.



Key Spacecraft Personnel		Affiliation
PM	C. M. Mackenzie	NASA-GSFC
PS	S. C. Freden	NASA-GSFC
MG	B. T. Nolan	NASA Headquarters
SC	R. I. Whitman	NASA Headquarters

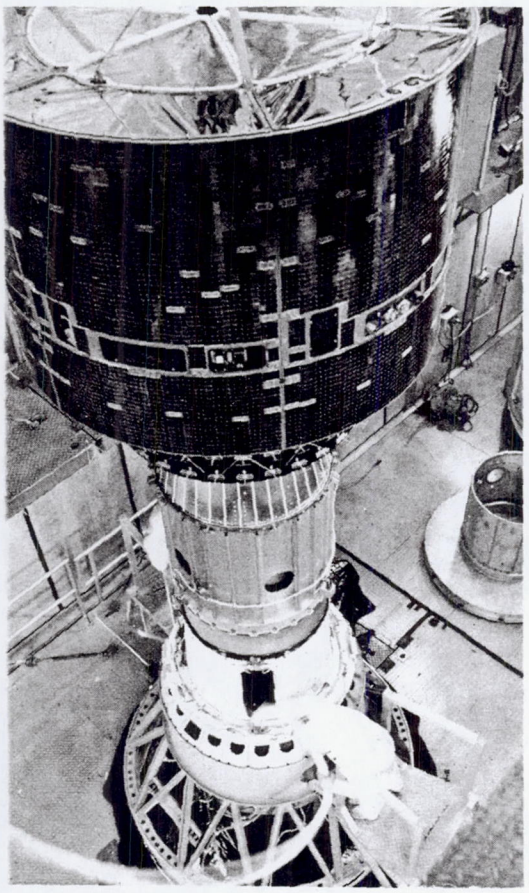
Experiment	Experiment Personnel		Affiliation
Videcon Camera System	PI	O. Weinstein	NASA-GSFC
	OI	T. M. Ragland	NASA-GSFC
Multi-Spectral Scanner System	PI	J. A. Balla	NASA-GSFC
Data Collection System	PI	J. E. Painter	NASA-GSFC

SYNCHRONOUS METEOROLOGICAL SATELLITE-B (SMS-B)

Launch Vehicle – Straight-Eight Delta. First stage thrust had 205,000 pounds. Carried nine strap-on solid propellant motors on first stage. Each Castor II solid generated 52,000 pounds of thrust. The second stage produced 9,800 pounds of thrust and was capable of restarting. It used a modified version of the Apollo Lunar Module Descent Engine developed by TRW for the moonlanding program. The third stage used a Thiokol solid motor that generated 14,100 pounds of thrust.

Spacecraft Description – Drum-shaped, measuring 345 centimeters (135.85 inches) high including magnetometers, which extended 83 cm (32.6 in.) beyond the spacecraft, and 190.5 cm (74.8 in.) in diameter, consisted of an aluminum honeycomb shelf, supported by struts and an apogee boost motor (ABM). The experiment section was enclosed by metallic cover and solar cell-covered side panels.

Project Objectives – Together with SMS-A, the satellite was to keep 24-hour watch on the Western Hemisphere and provide cloud-cover pictures every 30 minutes to weathermen out of the National Oceanic and Atmospheric Administration (NOAA). This continuous coverage was of special importance for short-term phenomena such as the severe storm systems that preclude tornadoes.

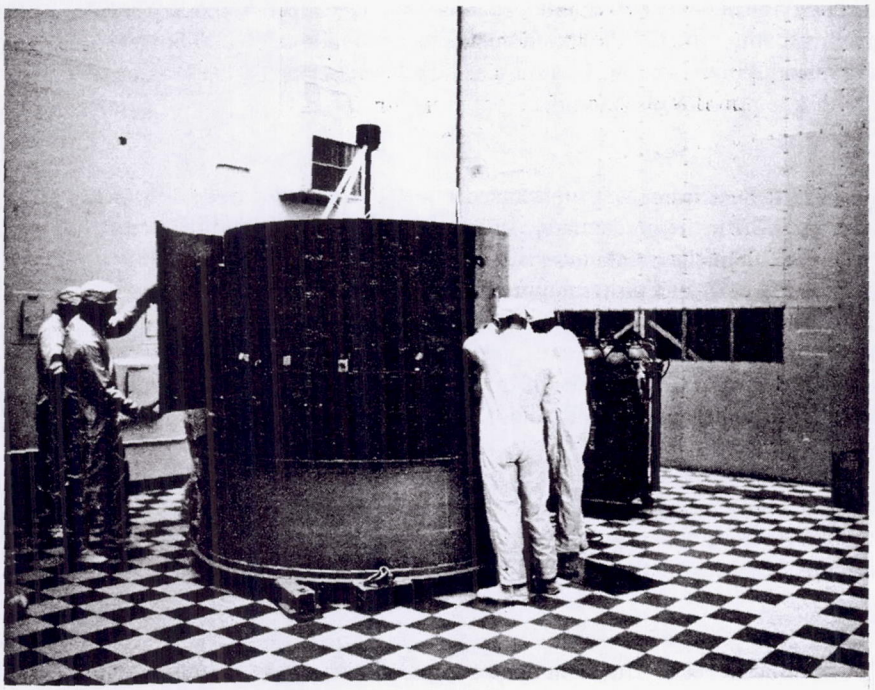


Spacecraft Payload – Weather camera – called a visible/infrared spin-scan radiometer; communications system to relay data from ground stations back to central collection point; space environment monitoring system to measure solar flare activity.

Project Results – SMS-B was launched February 6, 1975 from Kennedy Space Center and placed in geosynchronous orbit over the equator at 135 degrees west longitude, directly south of Sitka, Alaska and about 15 degrees southeast of Hawaii. From this position it viewed the western half of the United States and Hawaii.

Major Participants – Spacecraft management by NASA's Goddard Space Flight Center for the National Oceanic and Atmospheric Administration. Spacecraft prime contractor, Philco-Ford Corp. Launch vehicle management by NASA's Lewis Research Center. Prime contractor was McDonnell Douglas Corp.

Synchronous Meteorological Satellite-B (SMS-B) being erected atop its Delta booster prior to launch on February 6, 1975.



Pre-launch checkout of SMS-B.

Key Spacecraft Personnel		Affiliation
PM	D. Fordyce	NOAA-GSFC
PS	W.E. Shenk	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Solar Energetic Particles	PI	D. J. Williams	NOAA-ERL
	OI	H. H. Sauer	NOAA-ERL
Solar X-Ray Monitor	PI	D. J. Williams	NOAA-ERL
	OI	R. F. Donnelly	NOAA-ERL
Bi-Axis Fluxgate Magnetometer	PI	D. J. Williams	NOAA-ERL
	OI	J. N. Barfield	NOAA-ERL
Spin-Scan Radiometer	PI	Ness Staff	NOAA-NESS
	OI	W. E. Shenk	NASA-GSFC
Meteorological Data Collection System	CO	J. Puerner	NOAA-NESS
	PI	Ness Staff	NOAA-NESS

INTELSAT IV
F-6 & F-1

Launch Vehicle – Atlas Centaur: Atlas booster developed 430,000 pounds of thrust with two 185,000-pound main engines and one 60,000-pound sustainer, all liquid-fueled. Each of two liquid-fueled engines on the Centaur stage developed 15,000 pounds.

Spacecraft Description – Drum-shaped spin-stabilized main body 111 inches high and 93.7 inches in diameter. Antenna Array brought total spacecraft height to 208 inches. Antenna system, mounted on a despun platform, included two 50-inch dishes mounted side by side and four smaller horn antennas. Solar arrays covering the cylinder provided approximately 570 watts of power. Solid propellant apogee motor mounted at the base of the drum provided 10,000 pounds of thrust. Weight at launch, about 3,100 pounds; in orbit, about 1,600 pounds.

Project Objectives – Fourth-generation satellite to maintain Intelsat's global communications network. Each satellite had an average capacity of 4,000 circuits for voice or data, 12 TV channels, or combinations.

Spacecraft Payload – The communications subsystems was mounted on a mechanically despun platform and had six antennas; two global transmit, two global receive, and two steerable spot-beam transmit. The system had 12 transponders, each with a 36 MHz bandwidth.

Project Results – Flight 6 was launched from Kennedy Space Center, Florida on February 20, 1975. It was destroyed by the range safety officer after a launch vehicle malfunction. Flight I was launched May 22, 1975 from Kennedy Space Center and placed in service July 13, 1975 over the Indian Ocean at 63° E. longitude.

Major Participants – Spacecraft management, Comsat Corp. for Intelsat Organization; spacecraft prime contractor, Hughes Aircraft Co.; launch vehicle management, NASA Lewis Research Center; launch vehicle prime contractor, General Dynamics/Convair; apogee motor, Aerojet-General. Major suppliers from ten countries made up the international contractor team.

GEODYNAMICS EXPERIMENTAL OCEAN SATELLITE/ GEOS-C

Launch Vehicle – Two stage Delta, 106 feet long and 8 feet in diameter. McDonnell Douglas modified Thor booster first stage with four strap-on Thiokol Castor II solid fuel rocket motors and a TRW liquid-fuel pressure-fed powered second stage.

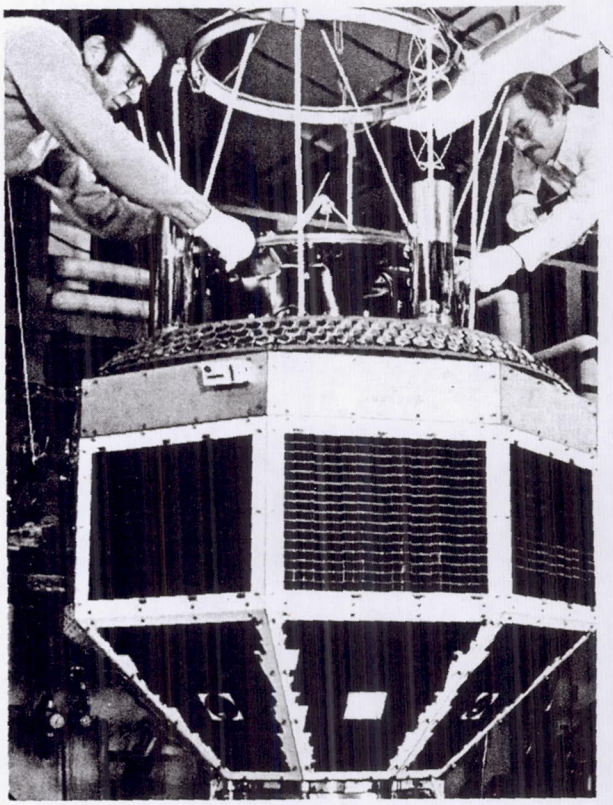
Spacecraft Description – Main body was an octagon 53 inches wide with a truncated pyramid below the base. The spacecraft was 32 inches high. Extending toward Earth from the Pyramid at the base of the octagon was a 235-inch scissor-type boom which held the end mass for the spacecraft's gravity gradient system, providing three-axis stabilization. Weight was 750 pounds.

Project Objectives – GEOS satellites were one element of NASA's satellite geodesy program, to provide precise measurements of the Earth's surface and shape and a mathematical description of its surface and gravity field. GEOS-A was originally known as Explorer 29 (1965). GEOS II was originally known as Explorer 36 (1968). Another satellite, called PAGEOS for the Passive GEOS, was launched in 1966. This mission was to demonstrate the feasibility for improved measurement techniques via satellites of such geodetic characteristics as ocean tides, sea state, gravity and solid-earth dynamics; evaluate new instruments for use in satellite geodesy and satellite orbit determination; verify ground truth observations; conduct a satellite-to-satellite tracking experiment with NASA's ATS-6.

Spacecraft Payload – A radar altimeter for measurement of ocean features such as sea state and wave height; two C-band transponders to support the altimeter and to determine GEOS accuracy for geometric and gravimetric geodesy measurements; an S-band transponder for the satellite-to-satellite tracking experiment; a radio Doppler system to obtain satellite range rate data; and a series of laser retroreflectors for measuring satellite range at optical frequencies.

Project Results – GEOS-C was launched April 9, 1975 from NASA's Western Test Range at Vandenberg AFB, California into a circular orbit of approximately 520 miles.

Major Participants – Spacecraft management, NASA Wallops Flight Center; spacecraft prime contractor, Johns Hopkins Applied Physics Laboratory; launch vehicle management, NASA Goddard Space Flight Center; launch vehicle prime contractor, McDonnell Douglas; launch operations, NASA Unmanned Launch Operations. More than 40 principal investigators took part in conducting and analyzing GEOS-C experiments.



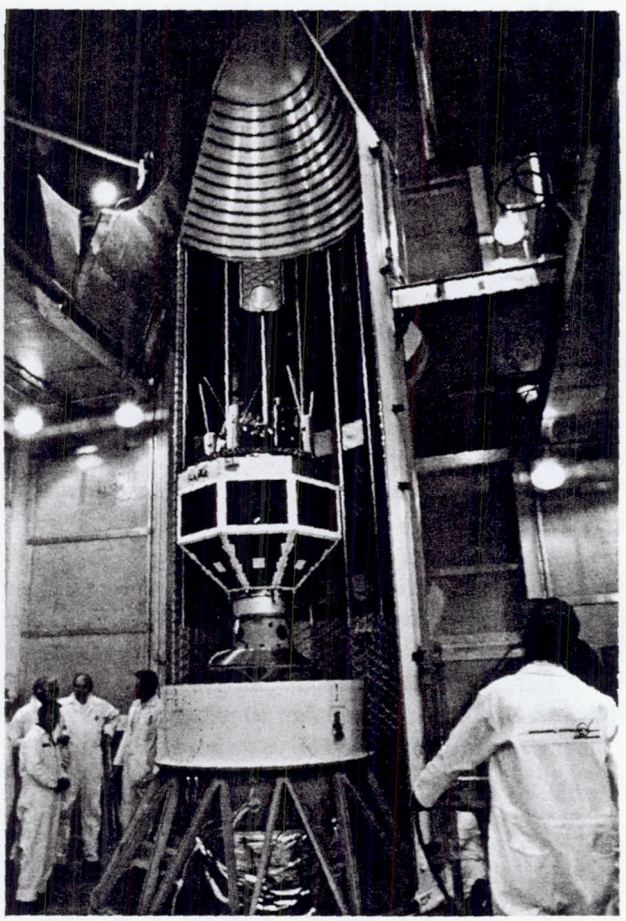
GEOS-C was prepared for launch at the Western Test Range, near Lompoc, Calif.

1975

Key Spacecraft Personnel		Affiliation
MG	C. J. Finley	NASA Headquarters
PS	H.R. Stanley	NASA-WFC
SC	J. P. Murphy	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Radar Altimeter System	PI	C. L. Purdy	NASA-WFC
S-Band Tracking System	PI	I. M. Salzberg	NASA-GSFC
C-Band System	PI	E. B. Jackson	NASA-WFC
Laser Cube System	PI	C. C. Stephanides	NASA-GSFC
U.S. Navy Doppler System	PI	R. J. Anderle	U.S. Naval Surface Weapons Center
Satellite to Satellite Tracking	PI	I. Y. Galicinao	NASA-GSFC
	CO	J. W. Bryan	Old Dominion Systems, Incorporated

GEOS-C satellite designed to measure ocean surface topography and wave activities is undergoing tests.



EXPLORER 53-
Small Astronomy Satellite-C

Launch Vehicle – Solid propellant Scout: 101,000-pound thrust Algol II first stage, 61,000-pound thrust Castor II second stage 21,000-pound thrust Antares II third stage, and an Altair III fourth stage. Height: 73 feet. Vehicle weight at liftoff: 40,000 pounds.

Spacecraft Description – Spin-stabilized satellite weighed 430 pounds and carried scientific payload in a separately fabricated section fitted to a common bus section. Bus was standard for all missions, and contained mission support subsystems such as power, attitude control, communications and data storage. Spacecraft measured 26 inches in diameter and 24 inches high. Four foldable solar panels provided power. Stability was provided by a reaction wheel and a passive nutation damper. Sun sensors, earth horizon sensor and a star sensor, as well as a magnetically torque control system could point the spacecraft to any point in the sky or vary its spin rate on command.

Project Objectives – To study x-ray sources within and beyond the Milky Way galaxy, as part of investigation of high-energy astrophysics.

Spacecraft Payload – The x-ray experiment carried four sub-experiments, each with its two star cameras to provide information for correlation of x-ray data with a specific object or region. The four sub-experiments included a galactic absorption experiment, a Scorpio monitor experiment (to view time variations in the x-ray source Sco X-1), a galactic monitor experiment and an extra-galactic experiment.

Project Results – SAS-C was launched May 7, 1975 from the San Marco launch facility, the Italian government's offshore launch platform located off the coast of Kenya. The initial orbit was equatorial.

Major Participants – Management of the spacecraft was by NASA's Goddard Space Flight Center, which also built the spacecraft. Massachusetts Institute of Technology's Center for Space Research designed and built the experiment. The University of Rome's Centro Ricerche Aerospaziali assembled, checked out and launched the spacecraft. The Italian government owned the offshore launch platform. Langley Research Center managed the Scout launch vehicle built by the Vought Systems Division of LTV Aerospace Corp., Arlington, Tex.

Key Spacecraft Personnel		Affiliation
PM	M. Towsend - launch	NASA-GSFC
PM	J.E. Kupperian, Jr. - operations	NASA-GSFC
PS	C.E. Fichtel	NASA-GSFC
MG	J.R. Holtz	NASA Headquarters
SC	N.G. Roman	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Extragalactic 1.5-10keV	PI	G. W. Clark	Massachusetts Institute of Technology
	OI	H. V. D. Bradt	Massachusetts Institute of Technology
	OI	W. H. G. Lewin	Massachusetts Institute of Technology
	OI	H. W. Schnopper	Massachusetts Institute of Technology
	CO	R. Rasche	Massachusetts Institute of Technology
Scorpio Monitor 0.4-80keV	PI	G. W. Clark	Massachusetts Institute of Technology
	OI	H. V. D. Bradt	Massachusetts Institute of Technology
	OI	W. H. G. Lewin	Massachusetts Institute of Technology
	OI	H. W. Schnopper	Massachusetts Institute of Technology
	CO	R. Rasche	Massachusetts Institute of Technology
Galactic Abs. 0.2-10keV	PI	G. W. Clark	Massachusetts Institute of Technology
	OI	H. V. D. Bradt	Massachusetts Institute of Technology
	OI	W. H. G. Lewin	Massachusetts Institute of Technology
	OI	H. W. Schnopper	Massachusetts Institute of Technology
	CO	R. Rasche	Massachusetts Institute of Technology
Galactic Monitor 1.8-8keV	PI	G. W. Clark	Massachusetts Institute of Technology
	OI	H. V. D. Bradt	Massachusetts Institute of Technology
	OI	W. H. G. Lewin	Massachusetts Institute of Technology
	OI	H. W. Schnopper	Massachusetts Institute of Technology
	CO	R. Rasche	Massachusetts Institute of Technology

ANIK 3/TELESAT-C

Launch Vehicle – Straight-Eight Delta. First stage thrust was 205,000 pounds. Carried nine strap-on solid propellant motors on first stage. Each Castor II solid generated 52,000 pounds of thrust. The second stage produced 9,800 pounds of thrust and was capable of restarting. It used a modified version of the Apollo Lunar Module Descent Engine developed by TRW for the moon-landing program. The third stage used a Thiokol solid motor that generated 14,100 pounds of thrust.

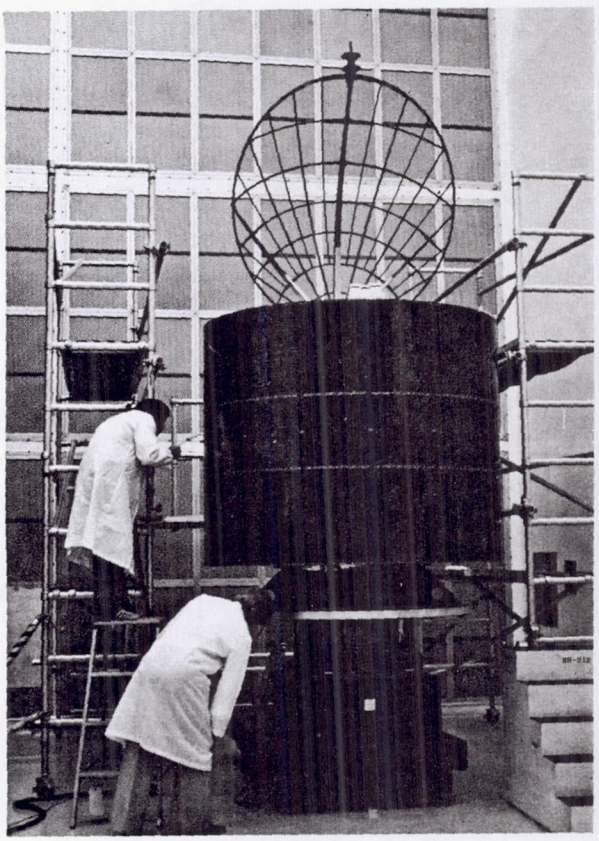
Spacecraft Description – A cylinder 75 inches in diameter and 11.6 feet tall. Weight at launch was about 1,250 pounds; weight in orbit was about 630 pounds. The spacecraft was spin-stabilized with despun antenna and feeds. The control system was redundant hydrazine thrusters with a seven-year station-keeping ability. Power was provided by about 23,000 solar cells with a 250-watt minimum; batteries provided 46-day eclipse power.

Project Objectives – Anik satellites were the spaceborne segment of the first Canadian domestic communications system using satellites at geosynchronous orbit. The system was owned jointly by the Canadian government and Canadian telecommunications common carriers (Telesat Canada). Two spacecraft were launched earlier – one in November 1972, the other in April 1973. "Anik" is the Eskimo word for brother. Anik 3 provided commercial communications services for Canada, which sprawls across nearly 4 million square miles. Some circuits also were leased to U.S. carriers for private line voice, data and video communications between east and west coasts and between both coasts and Alaska.

Spacecraft Payload – Twelve microwave channels, each carrying one color TV picture of 960 one-way telephone conversations. Uplink was in the 5.925 to 6.455 GHz band; downlink was in the 3.7 to 4.2 GHz band. The main antenna was a 60-inch parabola. Three-horn feed assembly accommodated receive and transmit frequencies.

Project Results – Anik 3 was launched May 7, 1975, from Kennedy Space Center, Florida. Its initial orbit was highly elliptical. On the seventh orbit an apogee kick motor was fired to transfer the spacecraft to its 22,300-mile geostationary orbit. Final station was at 104 degree west longitude.

Major Participants – Telesat Canada, owner. Spacecraft prime contractor, Hughes Aircraft Co. Major subcontractors, Spar Aerospace Products, Ltd., and Northern Electric, Ltd., both of Canada. Launch vehicle prime contractor, McDonnell Douglas Astronautics Co. Reimbursable launch services, NASA Kennedy Space Center.



The third in the series of Canadian domestic satellites, Telesat-C during final checkout and launch on May 7, 1975. In orbit the spacecraft was to be called ANIK-3, Eskimo for "brother."

1975

NIMBUS F

Launch Vehicle – Two stage Delta 2910.

Spacecraft Description – A butterfly-shaped spacecraft about 10 feet high and 11 feet wide. A five-foot-diameter ring lower section housed experiments and supporting equipment. Two solar panels provided more than 200 watts of power. The spacecraft was three-axis stabilized and weighs 1,823 pounds.

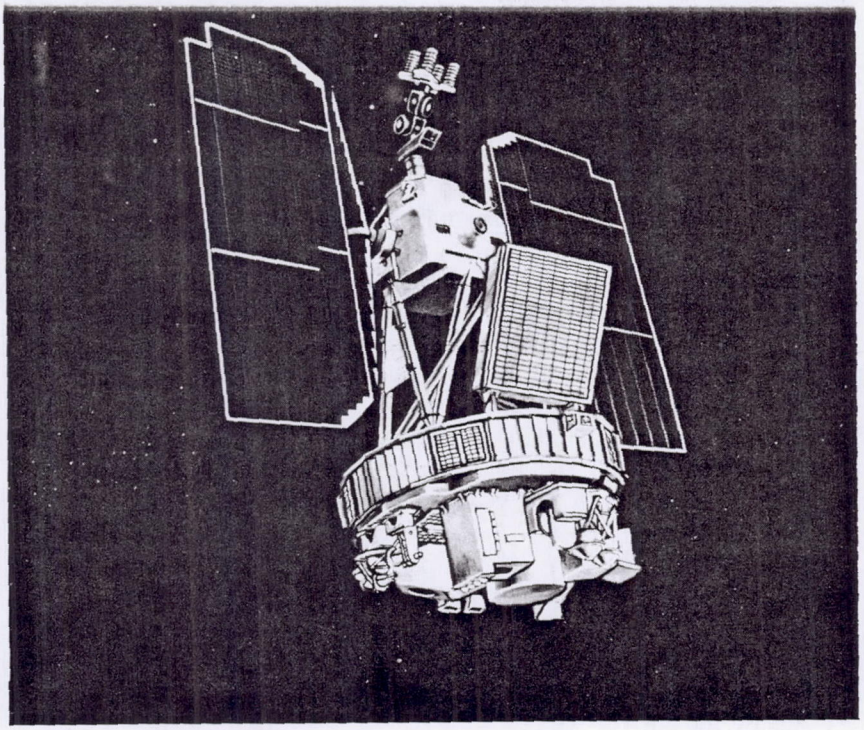
Project Objectives – Nimbus served as a testbed in NASA's meteorological program for research and development of new sensors, subsystems and system configurations. Improved systems and technology for weather prediction developed in Nimbus Improved systems and technology for weather prediction developed in Nimbus flights were utilized in operational meteorology spacecraft such as the ITOS series. Nimbus F was used in development of numerical models of the atmosphere and participated in the international Global Atmospheric Research Program. Continuation of development of new meteorological sensors, subsystems, and system configurations; study spatial and temporal distribution of the atmospheric structure, especially temperature, ozone and water vapor; provide a data base for long-range global weather forecasting.

Spacecraft Payload – Nine instruments: Earth radiation budget, Dr. W. Smith, NOAA; Electrically Scanning Microwave Radiometer, Dr. T. T. Wilheit, Goddard Space Flight Center; High-Resolution Infrared Radiation Sounder, A. W. McCulloch, Goddard; Limb Radiance Inversion Radiometer, J. C. Gille, National Center for Atmospheric Research (NCAR); Pressure Modulated Radiometer, Dr. J. T. Houghton, Oxford University; Scanning Microwave Spectrometer, Dr. D. Staelin, MIT; Tracking and Data Relay, F. O. Vonbun, Goddard; Temperature-Humidity Infrared Radiometer, A. W. McCulloch, Goddard; Tropical Wind, Energy Conversion and Reference Level, Dr. P. Julian, NCAR.

Project Results – Nimbus F was launched from NASA's Western Test Range at Vandenberg, California, June 12, 1975 into a near-polar, circular orbit.

Major Participants – Project management, NASA's Goddard Space Flight Center; structure, supporting systems and spacecraft integration and test, General Electric; Launch vehicle, McDonnell Douglas.

Key Spacecraft Personnel		Affiliation
PM	C. M. Mackenzie	NASA-GSFC
PS	M. Tepper	NASA-GSFC
CO	G. J. Delio	NASA-GSFC
CO	P. J. Crossfield	NASA-GSFC
MG	R. J. Arnold	NASA Headquarters



Nimbus F, meteorological satellite, was designed to test instruments for remote sensing of the Earth's atmosphere.

Experiment	Experiment Personnel		Affiliation
Trapped Wind Energy	OI	W. W. Kellogg	National Center for Atmospheric Research
	PI	P. Julian	National Center for Atmospheric Research
	OI	V. E. Suomi	University of Wisconsin
	OI	C. R. Laughlin	NASA-GSFC
	OI	R. L. Talley	Sigma Data Service Corporation
	OI	W. R. Bandeen	NASA-GSFC
	OI	C. E. Cote	NASA-GSFC
High Resolution Iridium Snder.	PI	W. L. Smith	NOAA-NESS
	OI	A. W. McCulloch	NASA-GSFC
	OI	H. Jacobowitz	NOAA-NESS
	OI	I. Ruff	NOAA-NESS
Elec. Scan. Micro Radiometer	PI	T. T. Wilheit, Jr.	NASA-GSFC
	OI	A. T. Edgerton	Aerojet Electrosystems
Limb Radiometer Inversion Radiometer	PI	J. C. Gille	National Center for Atmospheric Research
	OI	F. B. House	Drexel Institute of Technology
	OI	R. A. Craig	Florida State University
	OI	J. C. Bates	Unknown
Earth Radiation Budget	PI	H. Jacobowitz	NOAA-NESS
	OI	A. J. Drummond	Eppley Laboratory, Incorporated
	OI	I. Ruff	NOAA-NESS
	OI	J. R. Hickey	Eppley Laboratory, Incorporated
	OI	W. J. Scholes	Eppley Laboratory, Incorporated
	OI	L. L. Stowe	NOAA-NESS

Experiment	Experiment Personnel	Affiliation
Pressure Modulated Radiometer	PI J. T. Houghton	Oxford University
	OI C. D. Rodgers	Oxford University
	OI E. J. Williamson	Clarendon Laboratory
	OI G. D. Peskett	Clarendon Laboratory
	OI P. Curtis	Oxford University
Scanning Microwave Spectrum	PI D. H. Staelin	Massachusetts Institute of Technology
	OI F. T. Barath	NASA-JPL
	OI A. H. Barrett	Massachusetts Institute of Technology
	OI W. B. Lenoir	NASA-JSC
	OI W. Phillips	Massachusetts Institute of Technology
Temperature-Humidity Iridium Radiation	PI A. W. McCulloch	NASA-GSFC
Tracking and Data Relay	PI F. O. Vonbun	NASA-GSFC
	OI P. E. Schmid, Jr.	NASA-GSFC
	OI J. P. Brown	NASA-GSFC

OSO-8

Launch Vehicle – Two-stage Delta Straight-Eight.

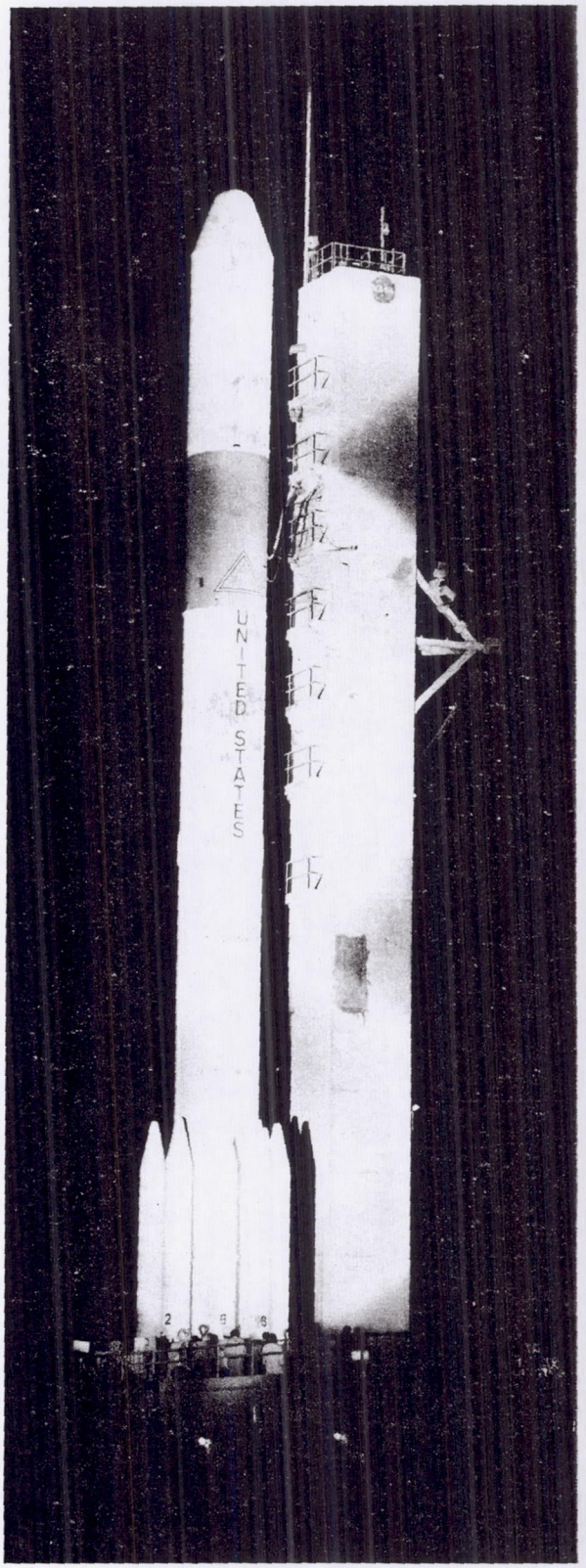
Spacecraft Description – A spin-stabilized craft with a despun platform to accommodate experiments that pointed at the sun or other sources of electromagnetic radiation. Experiments that needed no sustained pointing were carried in the rotating portion. OSO 8 weighed 2,346 pounds and had a designed lifetime of 12 months. The bottom section called the wheel was a cylinder 60 inches in diameter by 28.2 inches high. The rotating wheel accounted for 70 per cent of total spacecraft weight, including 555 pounds for the six experiments located there. The upper section was called the sail. The non-spinning sail provided power from solar cells and a platform that always looked at the sun for the two pointing experiments. The sail was 92.4 inches high and 82.5 inches wide. The two pointed experiments comprised a package about 15 inches square and 57 inches long that weighed 268 pounds. N on P solar cells and nickel-cadmium batteries provided 110 watts of power to the spacecraft and experiments. The wheel spin rate was 6 rpm and was controlled by a pneumatic system.

Project Objectives – To provide a better understanding of energy transfer in the sun's hot, gaseous atmosphere and a continuing study of the sun's 11-year sunspot cycle. To investigate celestial sources of X-rays in the Milky Way and beyond.

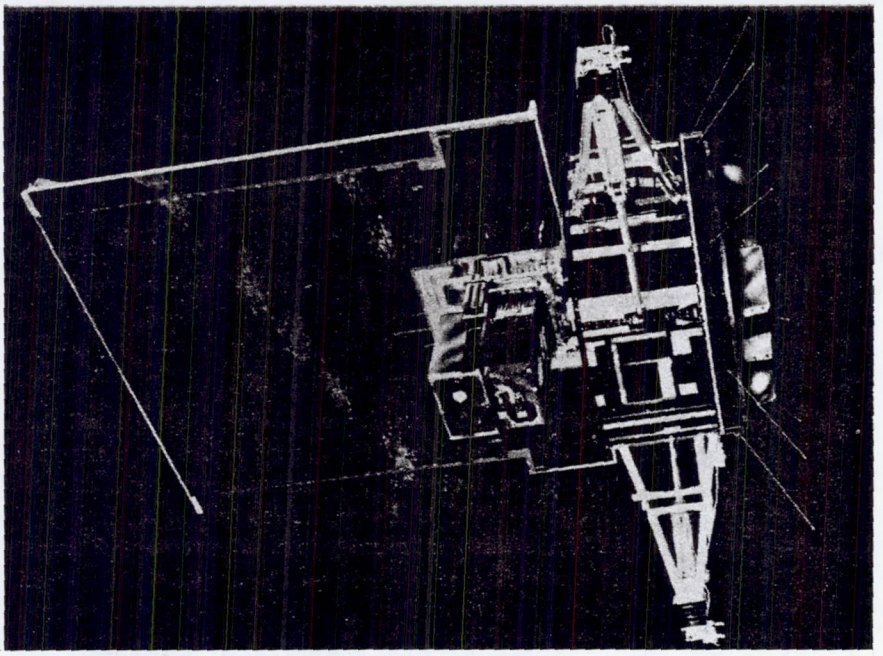
Spacecraft Payload – Eight experiments: a high-sensitivity crystal spectrometer and polarimeter; a mapping X-ray heliometer; investigation of soft X-ray background; cosmic X-ray spectroscope; high-energy celestial X-ray equipment; extreme ultraviolet radiations from earth and space instruments; two ultraviolet solar telescopes.

Project Results – OSO 8 was launched aboard a Delta rocket from Cape Canaveral, Fla., June 21, 1975 and was placed into a circular orbit.

Major Participants – Overall management by NASA's Office of Space Science, Project management by Goddard Space Flight Center; Goddard was also responsible for the Delta launch vehicle. Spacecraft prime contractor was Hughes Aircraft Co. Delta prime contractor was McDonnell Douglas.



Preparations at the Western Test Range prior to launch of OSO-8, June 21, 1975.



OSO-I (8) spacecraft to study specific features of the Sun. It was the 112th mission using a Delta rocket.

Key Spacecraft Personnel		Affiliation
PM	R. Pickard	NASA-GSFC
PS	S. Maran	NASA-GSFC
MG	M.E. McDonald	NASA Headquarters
SC	J.D. Bohlin	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
High-Resolution Ultra-violet Spectrometer	OI	E. C. Bruner, Jr.	Lockheed Palo Alto
	OI	R. G. Athay	High Altitude Observatory
	PI	C. A. Barth	University of Colorado
Chromosphere Fine-Structure	OI	P. Lemaire	CNRS-LPSP
	OI	A. Vidal-Madjar	CNRS-SA
	PI	R. M. Bonnet	CNRS-SA
	OI	J. C. Vial	CNRS-SA
Stellar and Solar X-Tal Spectroscope	PI	R. Novick	Columbia University
	OI	J. R. Angel	University of Arizona
	OI	P. A. Vandenbout	Columbia University
	OI	M. Weisskopf	Columbia University
	OI	R. S. Wolff	Columbia University
Mapping X-Ray Heliometer	OI	J. L. Culhane	University College of London
	PI	L. W. Acton	Lockheed Palo Alto
	OI	R. C. Catura	Lockheed Palo Alto
Soft X-Ray Background Radiation	PI	W. L. Kraushaar	University of Wisconsin
	OI	A. N. Bunner	University of Wisconsin
Cosmic X-Ray Spectroscopy	OI	F. A. Boldt	NASA-GSFC
	OI	S. S. Holt	NASA-GSFC
	PI	P. J. Serlemitsos	NASA-GSFC
	OI	D. Schwartz	SAO
High Energy Celestial X-Ray	PI	K. J. Frost	NASA-GSFC
	OI	B. R. Dennis	NASA-GSFC
EUV From Earth and Space Exp.	PI	C. S. Weller, Jr.	U.S. Naval Research Laboratory

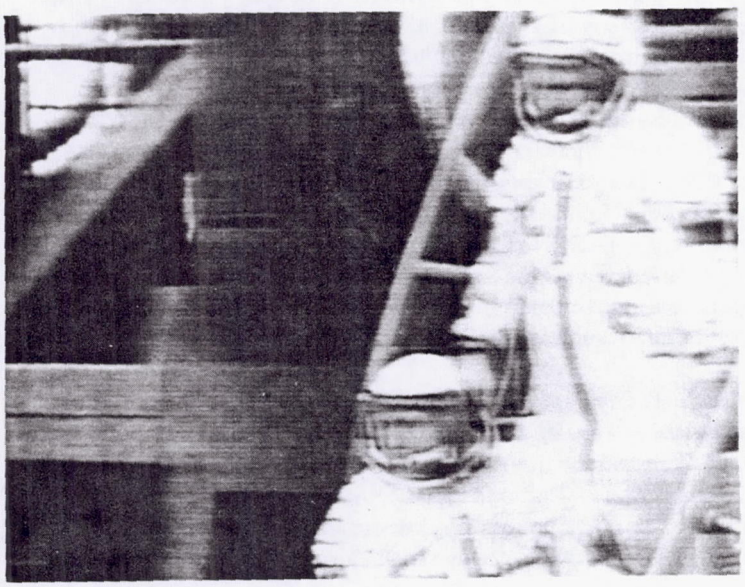
APOLLO-SOYUZ (US-USSR) TEST PROJECT

Launch Vehicle – Apollo: Saturn IB, consisting of S-IB first stage, S-IVB second stage, an instrument unit and a spacecraft-lunar module adapter. It was 224 feet tall, 21.7 feet in diameter and weighed 650 tons fully fueled. The ASTP launch was the 32nd and final flight of a Saturn-class vehicle.

Soyuz: Consisted of three stages, the first containing four "side units" each equipped with a four-chamber engine and two steering chambers having a thrust of 102 tons. The second stage was a 28-meter-long central unit with a four-chamber engine and four steering chambers with a thrust of 96 tons. The third stage was eight meters long and had a four-chamber engine with steering nozzles that generated thrust of 30 tons. The launch vehicle and spacecraft, fully fueled and equipped, weighed about 300 tons.

Spacecraft Description – Apollo: Standard lunar-mission command and service modules modified for controls that were needed to operate the common docking system. The command module weighed 13,105 pounds at launch. It was equipped with the standard Apollo probe and drogue latching system used in lunar and Skylab missions. The service module weighed 14,949 pounds at launch and contained 2,727 pounds of propellant for the service propulsion system engine. The docking module, essentially an airlock with docking facilities on each end to allow crew transfer between Apollo and Soyuz spacecraft, was 10 feet, four inches long, four feet, eight inches maximum diameter and weighed 4,436 pounds.

Soyuz: Standard Soyuz spacecraft. It weighed, according to Soviet Information, 6.8 tons, had a maximum length of 7.5 meters, maximum diameter of 2.72 meters. Diameter of the habitable modules was 2.2 meters; the solar-panel space was 8.37 meters, and the total volume of the habitable modules was 10 cubic meters. The Soyuz spacecraft consisted of three main modules: the descent vehicle, orbital module and instrument-assembly module. It was capable of flying a crew of two.



A televised picture of Commander Aleksey Leonov and Flight Engineer Valeriy Kubasov, the Soviet astronaut team of the Apollo-Soyuz mission.

Project Objectives – Rendezvous of two spacecraft from differing countries; spacecraft docking and undocking; intervehicular crew transfer; interaction of control centers, interaction of spacecraft crews; docked spacecraft attitude control; radio and cable communications; testing docking and undocking; onboard documentary photography; television transmission; joint experiments; separate experiments; joint communication and control through U.S. and USSR control centers.

Spacecraft Payload – In addition to the international cooperation mementos, including certificates that were signed by all crew members in orbit, the spacecraft carried the following experiments (also note listing below): extreme ultraviolet survey, Dr. C. S. Bowyer, UC Berkeley, principal investigator; helium glow, Dr. C. S. Bowyer, UC Berkeley, principal investigator; ultraviolet absorption, Dr. Thomas Donahue, University of Michigan, principal investigator; soft X-ray, Dr. Herbert Friedman, Naval Research Laboratory, principal investigator; electrophoresis, Prof. Kurt Hannig, Max Planck Institute, principal investigator; interface marking in crystals, Dr. Harry C. Gatos, MIT, principal investigator; crystal growth from the vapor phase, Dr. Herbert Wiedemeier, Rensselaer Polytechnic Institute, principal investigator; electrophoresis technology, Dr. Robert S. Snyder, Marshall Space Flight Center, principal investigator; light flash, Dr. T. F. Budinger, Lawrence Livermore Laboratory, principal investigator; Earth observations and photography, Dr. Farouk El-Baz, Smithsonian Institution, principal investigator; surface tension induced convection, Dr. R. E. Reed, Oak Ridge National Laboratories, principal investigator; USSR multiple material melting, Dr. I. Ivaniv, Soviet Academy of Science, principal investigator; microbial exchange, Dr. G. R. Taylor, Johnson Space Center, principal investigator; Doppler tracking, Dr. G. C. Weiffenbach and Dr. M. D. Grossi, Smithsonian Astrophysical Observatory, principal investigators; zero-G processing of magnets, Dr. D. J. Larson, Grumman Aerospace Corp., principal investigator; sodium chloride-lithium fluoride eutectic, Dr. Alfred S. Yue, UCLA, principal investigator; crystal growth, Dr. M.D. Lind, Science Center of Rockwell International Corp.; stratospheric aerosol measurement, Dr. T. J. Pepin, University of Wyoming; biostack, Prof. Horst Bucker, University of Frankfurt, principal investigator; geodynamics, Dr. F. O. Vonbun, Goddard Space Flight Center; zone-forming fungi, Dr. I. G. Akoev, USSR, principal investigator; monotectic and syntectic alloys, Dr. C. Y. Ang, Northrop Corp., principal investigator; artificial solar eclipse, Dr. G. M. Nikolsky, USSR, principal investigator; killifish hatching and orientation, Dr. William D. Scheld, Johnson Space Center, principal investigator; cellular immune response, Dr. B. Sue Criswell, Baylor College of Medicine; polymorphonuclear leukocyte response, Dr. R. R. Martin, Baylor College of Medicine, principal investigator; crystal activation, Dr. J. Trombka, Goddard Space Flight Center, principal investigator.

Project Results – The Soyuz spacecraft was launched from the Soviet cosmodrome at Baikonur at 7:20 a.m. (CDT) July 15, 1975. The Apollo spacecraft lifted off from Launch Complex 39B at Kennedy Space Center, Fla., about 7-1/2 hours later, at 2:50 p.m. (CDT). After a series of maneuvers to bring about rendezvous, Apollo and Soyuz began stationkeeping at 10:51 a.m. (CDT) July 17. Docking took place at 11:15 a.m. The first crew transfer

began at 11:17 a.m., and ended at 5:35 p.m. (CDT). After other transfers and activities, the two spacecraft undocked and conducted scientific and engineering experiments jointly and independently. At 5:11 a.m., July 21, the Soyuz crew performed their deorbit maneuver and the spacecraft re-entered the atmosphere to land within view of television cameras transmitting live coverage of the recovery – the first ever seen outside the Soviet Union. Apollo continued to orbit Earth for about 3-1/2 days more, finally splashing down at 4:18 p.m. (CDT, July 24).

Major Participants – Johnson Space Center was responsible for development of spacecraft, flight crew training and flight control. Marshall Space Flight Center developed the launch vehicle. Kennedy Space Center was responsible for Apollo/Saturn launch operations. Rockwell International Space Division designed and built command and service modules, docking system and provided spacecraft support. Rockwell's Rocketdyne Division provided Saturn engines and support. General Electric Co. provided automatic checkout equipment and launch vehicle ground support equipment. Chrysler Corp. provided S-1B stage and launch support. McDonnell Douglas Astronautics Co. provided S-IVB stage and support. IBM Federal Systems Division provided the instrument unit and IU launch support. ILC Industries provided astronauts' space suits. Boeing provided reliability and quality assurance at JSC.

Key Spacecraft Personnel		Affiliation
PM	C.M. Lee	NASA Headquarters
SC	R.T. Giuli	NASA-JSC

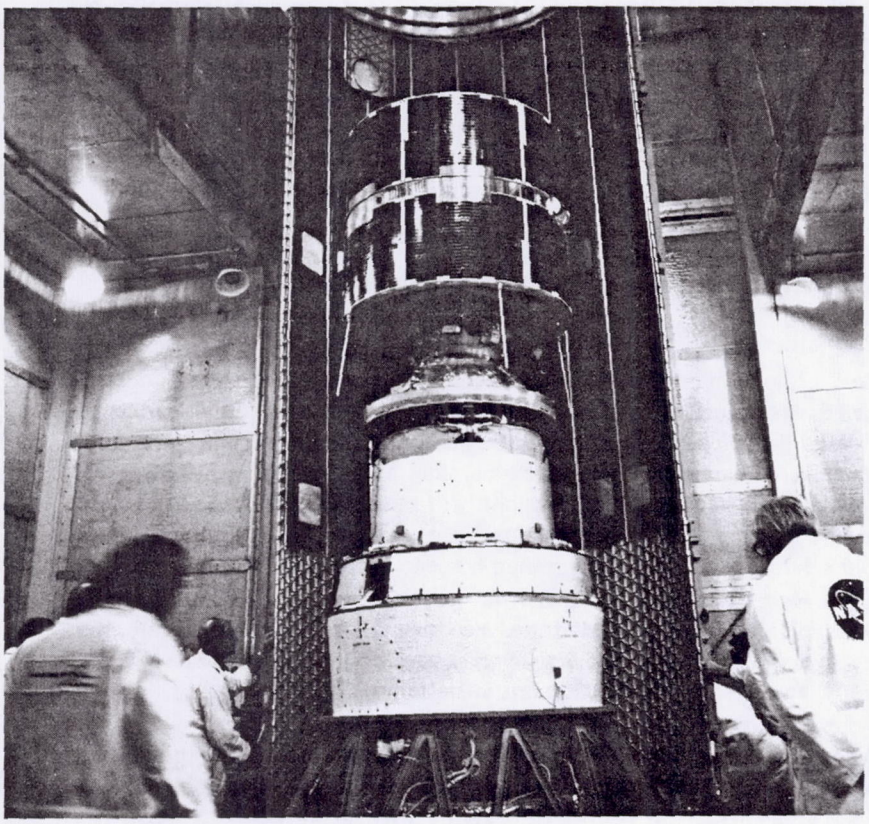
Experiment	Experiment Personnel		Affiliation
EUV Survey	PI	C.S. Bowyer	University of California, Berkeley
Helium Glow	PI	C.S. Bowyer	University of California, Berkeley
UV Atmospheric Absorption	PI	T.M. Donahue	University of Michigan
Sky-Earth Soft X-Ray	PI	H.D. Friedman	US Naval Research Laboratory
Surface Tension	PI	R.E. Reed	Oak Ridge National Laboratory
	OI	F.J. Bruni	Holifield National Laboratory
Mono. Syntectic Alloy	PI	C.Y. Ang	NASA-MSFC
	OI	L.L. Lacy	NASA-MSFC
Magnets in Zero-G	PI	D. Larson	Grumman Aerospace Corporation
	OI	T.Z. Kattamis	University of Connecticut

Experiment	Experiment Personnel		Affiliation
Interface Marks, Xtal.	PI	H.C. Gatos	Massachussets Institute of Technology
	OI	A.F. Witt	Massachussets Institute of Technology
Xtal. Growth, Zero-G	PI	H. Wiedemeier	Rensselaer Polytechnic
Nacl.-Lif. Eutectic.	PI	A.G. Yue	University of California, Los Angeles
	OI	C.W. Yeh	University of California, Los Angeles
Electrophoresis	PI	K. Hannig	MPI-Extraterrestrial Physics
Doppler Tracking	PI	G.C. Weiffenbach	Smithsonian Astrophysical Observatory
Leukocyte Response	PI	R.R. Martin	Baylor University
Cell. Immune Response	PI	R.S. Criswell	Baylor University
Biostack	PI	H. Bucker	DFVLR
Light Flashes	PI	T.F. Budinger	University of California, Berkeley
Geodynamics	PI	F.O. Vonbun	NASA-GSFC
Crystal Growth	PI	M.D. Lind	Rockwell International Scientific Center
Statosph-Aerosols	PI	T.J. Pepin	University of Wyoming
Electrophoresis Tech	PI	R.E. Allen	NASA-MSFC
Earth Obs + Photos	PI	F. El-Baz	Smithsonian Institution
Crystal Activation	PI	J.I. Trombka	NASA-GSFC
Killifish Hatch + Ornt	PI	H.W. Scheld	University of Houston
Zone forming Fungi	PI	I.G. Akoev	Unknown



Soyuz liftoff from Soviet Cosmodrome at Baykonur.

COS-B



COS-B is readied for launch at Western Test Range, Calif. A project of the European Space Agency, ESA, it was placed into a highly elliptical orbit to observe extraterrestrial gamma radiation.

Launch Vehicle – Delta 2913. (Delta Straight-Eight)

Spacecraft Description – A cylindrical, 280-kilogram satellite carrying one large astronomy experiment.

Project Objectives – Investigation of gamma radiation from exploding stars, quasars, pulsars, and other radio and X-ray sources.

Spacecraft Payload – Astronomy experiment featured 16-gap spark chamber for determination of the arrival direction of gamma quanta; cesium-iodide energy calorimeter for energy determination; telescope for defining experiment field of view; and a plastic-scintillator anticoincidence shield for rejection of charged particles. Also a proportional counter for X-rays in the 2 - 12 keV range.

Project Results – COS-B was successfully launched from the Western Test Range near Lompoc, California on August 8, 1975.

Major Participants – Project management, European Space Agency's ESTEC Center; and industrial team consisting of firms from Belgium, Denmark, France, Germany, Italy, Spain and the United Kingdom produced the spacecraft; science institutes in France, Germany, Italy and the Netherlands provided the astronomy experiment.

VIKING A

Launch Vehicle – Titan-Centaur – Combined Centaur upper stage with the Tital III booster. Centaur was the nation's first high-energy liquid hydrogen-liquid oxygen rocket. It developed 133,440 newtons (30,000 pounds) of thrust at altitude. The Tital was a two-stage liquid propellant core rocket having two large 120-inch diameter strap-on solid rocket motors which developed 10.6 million newtons (2.4 million pounds) thrust at liftoff. This was the first successful operational flight of the Titan Centaur rocket.

Spacecraft Description – Viking was divided into an orbiter portion and a lander.

The 5,125-pound orbiter vaguely resembled a scale-up Mariner spacecraft, since the arrangement of components was generally similar and Mariner design philosophy was employed throughout. The orbiter main structure was a flat, octagonal prism with unequal sides 85 by 99.2 inches along diagonals. Louvers around the periphery of the octagon opened and closed automatically to provide individual thermal control to 16 equipment bays. Four solar panels were hinged at their bases to outrigger structures and hinged again halfway out. Together the panels provided 23,250 square inches of solar cells. At Mars' distance they generated 620 watts of power. Supplementary power for peak loading and for dark times was provided by two 30-ampere-hour nickel-cadmium batteries.

The orbiter's communication system was used as a relay between the lander on the Martian surface and the Earth. A parabolic, high-gain antenna, 57.9 inches in diameter, was motor-driven about two axes. A rod-like low-gain antenna on the sunlit side of the spacecraft allowed limited two-way communications with Earth over greater than hemisphere coverage. A third antenna, mounted on the end of one solar panel, was for communication between orbiter and lander. The orbiter's transmitter power was about 20 watts, allowing transmission of 4,000 bits per second to a 210-foot-diameter DSN station.

The orbiter carried three instruments, and performed four experiments. Two narrow-angle television cameras provided high-resolution imaging and was first used for landing-site verification. An atmospheric water detector mapped the super-dry atmosphere of Mars for what water vapor may be there. (Mariner 9 showed signs of water vapor escaping the atmosphere.) An infrared thermal mapper also covered the planet's surface for signs of warmth. And the spacecraft radio provided data for an occultation experiment to provide data on the planet's size, gravity, mass, density and other physical characteristics.

The 2,353-pound lander became the first U.S. spacecraft to land on another planet. (U.S. and Soviet spacecraft have landed on the moon, a satellite of Earth. Soviet spacecraft have landed on Mars and Venus.) The lander was encapsulated in a bioshield before it was launched to keep it from carrying Earth organisms from contaminating Mars – and the biology instrument. Inside the bioshield, which was discarded after reaching the vacuum of space, was an aeroshell that acted as a heat shield during Martian entry.

The lander body was a hollow; six-sided aluminum box 18.2 inches deep enclosed by a top and bottom cover plate. The six sides were 43 inches and 22 inches alternately. The three landing leg units were attached to the shorter sides. Three landing legs were provided instead of four to provide maximum stability.

The lander body provided mounting surfaces on the outside for the two cameras, meteorology boom, surface sampler boom, seismometer, power generators, antennas, descent engines, field tanks, inertial reference unit, various control boxes and the soil inlets for the organic, inorganic and biology instruments. The interior of the body was an environmentally controlled compartment for the biology instrument, gas chromatograph/mass spectrometer, computer, tape recorder, data storage memory, batteries, radios, data acquisition and processing unit and command control and support units.

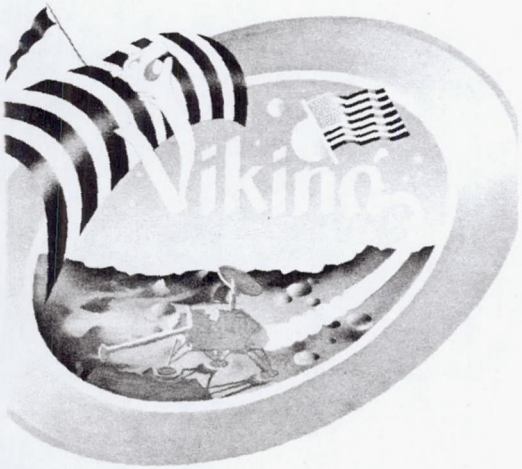
Landing sequence began when the lander and orbiter were separated and the lander aeroshell made initial contact with the Martian atmosphere. After atmospheric drag had reduced the spacecraft's speed to 1,230 feet per second, an 80-foot parachute was deployed. At 4,000 feet altitude the parachute was jettisoned and terminal descent engines reduced velocity to only a few feet per second. These engines shut down just above the Martian surface. There were three main terminal descent engine clusters, each containing 18 tiny nozzles. Engineers adopted this design to spread exhaust gases from ultrapure hydrazine so as to minimize the possibility of surface contamination.

Project Objectives – to conduct a systematic investigation of Mars from orbit and from the surface, with primary emphasis on the search for life.

Spacecraft Payload – Three instruments and the spacecraft radio on the orbiter and nine instruments on the lander; Orbiter experiments – high-resolution camera, atmospheric water-vapor mapper, surface heat mapper, occultation experiment. Lander experiments – biology instrument, gas chromatograph/mass spectrometer, x-ray fluorescence spectrometer, seismometer, meteorology instrument, stereo color cameras, physical and magnetic properties of soil, aerodynamic properties and composition of Martian atmosphere with changes in altitude.

Project Results – Viking A was launched from NASA Kennedy Space Center on Aug. 20, 1975; it successfully soft-landed on July 20, 1976.

Major Participants – Program management by NASA's Langley Research Center, Hampton, Va. Control and orbiter construction by Jet Propulsion Laboratory, Pasadena, Calif. Orbiter prime contractor, Martin Marietta Corp., Denver, Colo. Launch vehicle management by the U.S. Air Force Space and Missile Systems Organization and NASA Lewis Research Center, Launch-vehicle prime contractors, Martin Marietta and General Dynamics Convair.



'tist Don David's interpretation of Viking ission to Mars. The first spacecraft was unched on August 20, 1975 followed by king-B on September 9, 1975, each com- sed of an orbiter and instrument-carrying ıder.

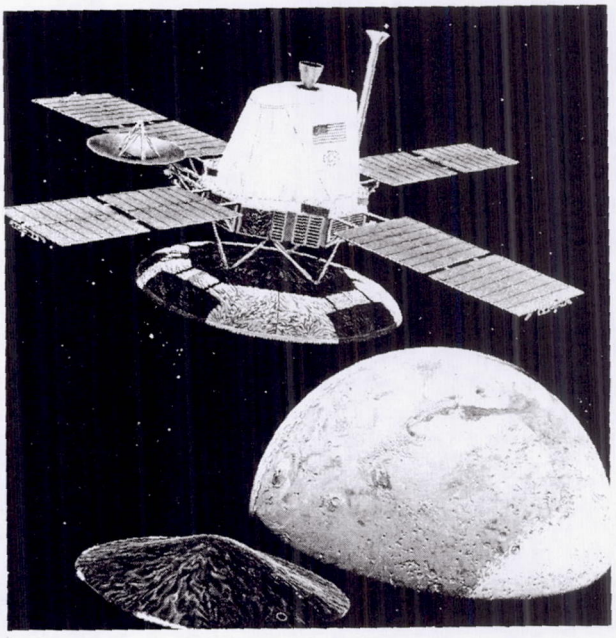
Key Spacecraft Personnel		Affiliation
Viking 1 Orbiter		
PM	C.M. Lee	NASA Headquarters
SC	R.T. Giuli	NASA-JSC
PM	K.S. Watkins	NASA-JPL
PS	C.W. Snyder	NASA-JPL
MG	W. Jakobowski	NASA Headquarters
SC	R.S. Young	NASA Headquarters
Viking 1 Lander		
PM	K.S. Watkins	NASA-JPL
PS	C.W. Snyder	NASA-JPL
MG	W. Jakobowski	NASA Headquarters
SC	R.S. Young	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Viking 1 Orbiter			
Imagery	TL	M.H. Carr	US Geological Survey
	TM	W.A. Baum	Lowell Observatory
	TM	H. Masursky	US Geological Survey
	TM	G.A. Briggs	NASA Headquarters
	TM	J.A. Cutts	Science Applications, Incorporated
	TM	T.C. Duxbury	NASA-JPL
	TM	K.R. Blasius	Science Applications, Incorporated
	TM	R. Greeley	Arizona State University
	TM	J.E. Guest	University of London
	TM	K.A. Howard	US Geological Survey
	TM	B.A. Smith	University of Arizona
	TM	L.A. Soderblom	US Geological Survey
	TM	J. Veverka	Cornell University
	TM	J.B. Wellman	NASA-JPL
Radiometer	TL	H.H. Kieffer	US Geological Survey
	TM	G. Munch	California Institute of Technology
	TM	E.D. Miner	NASA-JPL
	TM	G. Neugebauer	California Institute of Technology
	TM	S.C. Chase, Jr.	Santa Barbara Research Center
	TM	F.D. Palluconi	NASA-JPL
Spectrometer	TL	C.B. Farmer	NASA-JPL
	TM	D.D. Laporte	Santa Barbara Research Center
	TM	D.W. Davies	NASA-JPL

Experiment	Experiment Personnel		Affiliation
Viking 1 Orbiter			
Radio Science	TL	W.H. Michael, Jr.	NASA-LARC
	TM	I.I. Shapiro	Massachusetts Institute of Technology
	TM	G.F. Lindal	NASA-JPL
	TM	J.G. Davies	University of Manchester
	TM	D.L. Cain	NASA-JPL
	TM	M.D. Grossi	Raytheon Corporation
	TM	G.L. Tyler	Stanford University
	TM	J.P. Brenkle	NASA-JPL
	TM	R.H. Tolson	NASA-LARC
	TM	C.T. Stelzried	NASA-JPL
	TM	G. Born	NASA-JPL
	TM	R. Reasenberg	Massachusetts Institute of Technology
Viking 1 Lander			
Physical Properties	TM	R.F. Hutton	TRW Systems Group
	TM	H.J. Moore, II	US Geological Survey
	TM	R.F Scott	California Institute of Technology
	TL	R.W. Shorthill	University of Utah
Atmospheric Structure	TL	A.O.C. Nier	University of Minnesota
	TM	A. Seiff	NASA-ARC
	TM	N.W. Spencer	NASA-GSFC
Biology	TL	H.P. Klein	NASA-ARC
	TM	J. Lederberg	Stanford University
	TM	A. Rich	Massachusetts Institute of Technology
	TM	N.H. Horowitz	California Institute of Technology
	TM	V.I. Oyama	NASA-ARC
	TM	G.V. Levin	Biospherics, Incorporated
Molecular Analysis	TL	K. Biemann	Massachusetts Institute of Technology
	TM	H.C. Urey	University of California, San Diego
	TM	D.M. Anderson	USA-CRREL
	TM	T. Owen	State University of New York
	TM	J. Oro	University of Houston
	TM	L.E. Orgel	Salk Institute Biological Studies
	TM	A.O.C. Nier	University of Minnesota
	TM	P. Toulmin, III	US Geological Survey

Experiment	Experiment Personnel		Affiliation
Viking I Lander			
Soil Water	TL	R.W. Shorthill	University of Utah
	TM	H.J. Moore, II	US Geological Survey
	TM	R.F. Scott	California Institute of Technology
	TM	R.E. Hutton	TRW Systems Group
Lander Imaging	TL	T.A. Mutch	NASA Headquarters
	TM	C. Sagan	Cornell University
	TM	A.B. Rinder	University of Kiel
	TM	E.C. Morris	US Geological Survey
	TM	F.O. Huck	NASA-LARC
	TM	E.C. Levinthal	Stanford University
	TM	S. Liebes, Jr.	Stanford University
	TM	J.B. Pollack	NASA-ARC
	TM	R.E. Arvidson	Washington University
Meteorology	TL	S.L. Hess	Florida State University
	TM	C.B. Leovy	University of Washington
	TM	R.M. Henry	University of Washington
	TM	J.A. Ryan	California State University Fullerton
	TM	J.E. Tillman	University of Washington
Seismology	TL	D.L. Anderson	California Institute of Technology
	TM	M.N. Toksoz	Massachusetts Institute of Technology
	TM	G.H. Sutton	University of Hawaii
	TM	R.L. Kovach	Stanford University
	TM	G.V. Latham	University of Texas, Galveston
	TM	F. Duennebier	University of Hawaii
Magnetic Properties	TL	R.B. Hargraves	Princeton University
Radio Science	TL	W.H. Michael, Jr.	NASA-LARC
	TM	I.I. Shapiro	Massachusetts Institute of Technology
	TM	G.F. Lindal	NASA-JPL
	TM	J.G. Davies	University of Manchester
	TM	D.L. Cain	NASA-JPL
	TM	M.D. Grossi	Raytheon Corporation
	TM	G.L. Tyler	Stanford University
	TM	J.P. Brenkle	NASA-JPL
	TM	R.H. Tolson	NASA-LARC
	TM	C.T. Stelzried	NASA-JPL
	TM	G. Born	NASA-JPL
	TM	R. Reasenberg	Massachusetts Institute of Technology

Experiment	Experiment Personnel		Affiliation
Atmospheric Composition	TL	A.O.C. Nier	University of Minnesota
	TM	M.B. McElroy	Harvard University
	TM	N.W. Spencer	NASA-GSFC
Inorganic Chemical Investigations	TL	P. Toulmin III	US Geological Survey
	TM	A.K. Baird	Pomona College
	TM	K. Keil	University of New Mexico
	TM	H.J. Rose	US Geological Survey
	TM	B.C. Clark	Martin-Marietta Aerospace
Ionospheric Properties	TL	A.O.C. Nier	University of Minnesota
	TM	W.B. Hanson	University of Texas, Dallas
	TM	N.W. Spencer	NASA-GSFC



The orbiter is shown at the top with planet Mars below it. The lander still enclosed in protective shell, has been released from orbiter and is headed for planet's surface. Parachute to deploy at 20,000 feet with retrorockets to slow down craft for soft landing.

Viking landing sites: Viking-A targeted for Chryse; Viking-B for Cydonia. Landings, occurring in mid-1976, were to be observed as part of the Nation's 200th Anniversary.



SYMPHONIE-B

Launch Vehicle – Delta 2914.

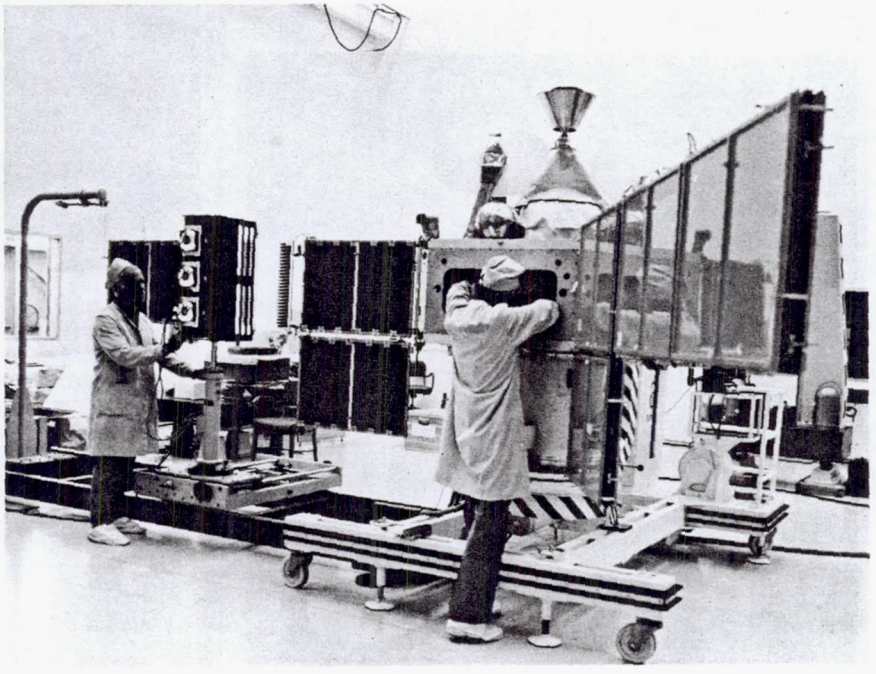
Spacecraft Description – Hexagonal main structure 6 feet in diameter and 1.6 feet high. Atop the structure was the super high frequency antenna feed and reflectors, and the reflectors, and the reception horn. VHF antennas were on the underside of the structure. Three solar arrays extended from the sides of the spacecraft at 120° intervals. Symphonie weighed about 875 pounds.

Project Objectives – Provide additional spaceborne communications link for system operating between points in Europe, the Americas, Africa and the Middle East.

Spacecraft Payload – Super high frequency communications system; Symphonie-B also carried a VHF system.

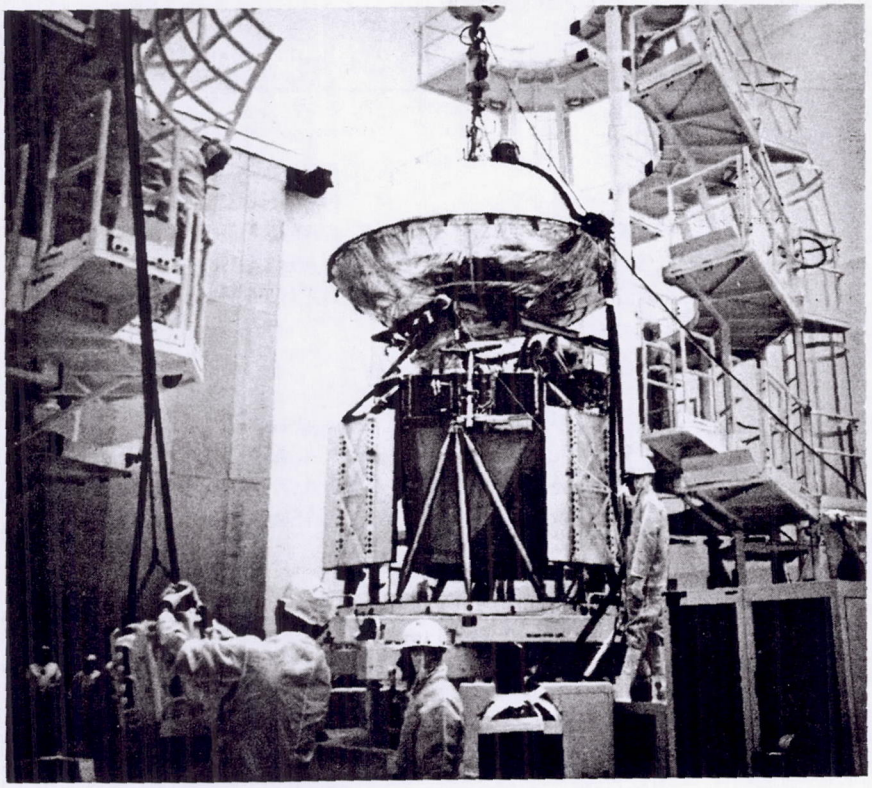
Project Results – Symphonie B was placed in operation after a successful launch from Cape Canaveral, Florida on August 26, 1975.

Major Participants – Spacecraft management, the Centre National d'Etudes Spatiales (CNES), and the Gesellschaft fur Weltraumforschung (GFW). Prime contractor was Consortium Industriel Franco-Allemand pour Symphonie (CIFAS), a Franco-German industrial consortium. The French firms were Société Nationale Aerospatiale, Société Anonyme de Télécommunications (S.A.T.) and Thomson-CSF, Germany's were AEG-Telefunken, Messerschmitt-Boelkow Blohm (MBB) and Siemens. A. G. Launch vehicle management, NASA Goddard Space Flight Center. Launch vehicle prime contractor was McDonnell Douglas Astronautics Co.



Symphonie-B, a joint French-West German space communications project, was launched from Kennedy Space Center, on August 26, 1975.

VIKING B



Mating of the first Viking orbiter and nuclear-powered lander. In 1975 NASA launched two spacecraft to study the planet Mars. Viking-A was launched on August 20, 1975, and soft landed July 20, 1976; Viking-B was launched on September 9, 1975, and successfully soft landed on September 3, 1976. They were the first United States attempts to soft land a spacecraft on another planet.

Launch Vehicle – Tital-Centaur – Combined Centaur upper stage with the Titan III booster. For further details see Viking-A.

Spacecraft Description – See Viking -A.

Project Objectives – To continue systematic investigation of Mars from orbit and from the surface, with primary emphasis on the search for life.

Spacecraft Payload - Three instruments and the spacecraft radio on the orbiter and nine instruments on the lander. Orbiter experiments – high-resolution camera, atmospheric water-vapor mapper, surface heat mapper, occultation experiment. Lander experiments – biology instrument, gas chromatograph/mass spectrometer, x-ray fluorescence spectrometer, seismometer, meteorology instrument, stereo color cameras, physical and magnetic properties of soil, aerodynamic properties and composition of Martian atmosphere with changes in altitude.

Project Results – Viking B was launched Sept. 9, 1975, successfully soft-landing on Mars September 3, 1976.

Major Participants – Program management by NASA's Langley Research Center, Hampton, Va. Control and orbiter construction by Jet Propulsion Laboratory, Pasadena, Calif. Orbiter prime contractor, Martin Marietta Corp., Denver, Colo. Launch vehicle management by the U.S. Air Force Space and Missile Systems Organization and NASA Lewis Research Center, Launch vehicle prime contractors, Martin Marietta and General Dynamics Convair.

Key Spacecraft Personnel		Affiliation
Viking B Orbiter		
	PM K.S. Watkins	NASA-JPL
	PS C.W. Snyder	NASA-JPL
	MG W. Jakobowski	NASA Headquarters
	SC R.S. Young	NASA Headquarters
Viking B Lander		
	PM K.S. Watkins	NASA-JPL
	PS C.W. Snyder	NASA-JPL
	MG W. Jakobowski	NASA Headquarters
	SC R.S. Young	NASA Headquarters

Experiment	Experiment Personnel	Affiliation
Viking B Orbiter		
Imagery	TI M.H. Carr	US Geological Survey
	TM W.A. Baum	Lowell Observatory
	TM H. Masursky	US Geological Survey
	TM G.A. Briggs	NASA Headquarters
	TM J.A. Cutts	Science Applications Incorporated
	TM T.C. Duxbury	NASA-JPL
	TM K.R. Blasius	Science Applications Incorporated
	TM R. Greeley	Arizona State University
	TM J.F. Guest	University of London
	TM K.A. Howard	US Geological Survey
	TM B.A. Smith	University of Arizona
	TM L.A. Soderblom	US Geological Survey
	TM J. Veverka	Cornell University
	TM J.B. Wellman	NASA-JPL
Radiometer	TL H.H. Kieffer	US Geological Survey
	TM G. Munch	California Institute of Technology
	TM E.D. Miner	NASA-JPL
	TM G. Neugebauer	California Institute of Technology
	TM S.C. Chase, Jr.	Santa Barbara Research Center
	TM F.D. Palluconi	NASA-JPL
Spectrometer	TL C.B. Farmer	NASA-JPL
	TM D.D. Laporte	Santa Barbara Research Center
	TM D.W. Davies	NASA-JPL

Experiment	Experiment Personnel		Affiliation
Viking B Orbiter			
Radio Science	TL	W.H. Michael, Jr.	NASA-LARC
	TM	I.I. Shapiro	Massachusetts Institute of Technology
	TM	G.F. Lindal	NASA-JPL
	TM	J.G. Davies	University of Manchester
	TM	D.I. Cain	NASA-JPL
	TM	M.D. Grossi	Raytheon Corporation
	TM	G.L. Tyler	Stanford University
	TM	J.P. Brenkle	NASA-JPL
	TM	R.H. Tolson	NASA-LARC
	TM	C.T. Stelzried	NASA-JPL
	TM	G. Born	NASA-JPL
	TM	R. Reasenberg	Massachusetts Institute of Technology
Viking B Lander			
Physical Properties	TM	R.E. Hutton	TRW Systems Group
	TM	H.J. Moore, II	US Geological Survey
	TM	R.F. Scott	California Institute of Technology
	TL	R.W. Shorthill	University of Utah
Atmospheric Structure	TL	A.O. C. Nier	University of Minnesota
	TM	A. Seiff	NASA-ARC
	TM	N.W. Spencer	NASA-GSFC
Biology	TL	H.P. Klein	NASA-ARC
	TM	J. Lederberg	Stanford University
	TM	A. Rich	Massachusetts Institute of Technology
	TM	N.H. Horowitz	California Institute of Technology
	TM	V.I. Oyama	NASA-ARC
	TM	G.V. Levin	Biospherics, Incorporated
Molecular Analysis	TL	K. Biemann	Massachusetts Institute of Technology
	TM	H.C. Urey	University of California, San Diego
	TM	D.M. Anderson	USA-CRREL
	TM	T. Owen	State University of New York
	TM	J. Oro	University of Houston
	TM	L.E. Orgel	Salk Institute Biological Studies
	TM	A O.C. Nier	University of Minnesota
	TM	P. Toulmin, III	US Geological Survey

Experiment	Experiment Personnel		Affiliation
Lander Imaging	TL	T.A. Mutch	NASA Headquarters
	TM	C. Sagan	Cornell University
	TM	A.B. Binder	University of Kiel
	TM	E.C. Morris	US Geological Survey
	TM	F.O. Huck	NASA-LARC
	TM	E.C. Levinthal	Stanford University
	TM	S. Liebes, Jr.	Stanford University
	TM	J.B. Pollack	NASA-ARC
	TM	R.E. Arvidson	Washington University
Meteorology	TL	S.L. Hess	Florida State University
	TM	C.B. Leovy	University of Washington
	TM	R.M. Henry	University of Washington
	TM	J.A. Ryan	California State University, Fullerton
	TM	J.E. Tillman	University of Washington
Seismology	TL	D.L. Anderson	California Institute of Technology
	TM	M.N. Toksoz	Massachusetts Institute of Technology
	TM	G.H. Sutton	University of Hawaii
	TM	R.L. Kovach	Stanford University
	TM	G.V. Latham	University of Texas, Galveston
	TM	F. Duennebier	University of Hawaii
Magnetic Properties	TL	R.B. Hargraves	Princeton University
Radio Science	TL	W.H. Michael, Jr.	NASA-LARC
	TM	I.I Shapiro	Massachusetts Institute of Technology
	TM	G. Fjeldbo	NASA-JPL
	TM	J.G. Davies	University of Manchester
	TM	D.L. Cain	NASA-JPL
	TM	M.D. Grossi	Raytheon Corporation
	TM	G.I. Tyler	Stanford University
	TM	J.P. Brenkle	NASA-JPL
	TM	R.H. Tolson	NASA-LARC
	TM	C.T. Stelzried	NASA-JPL
	TM	G. Born	NASA-JPL
	TM	R. Reasenberg	Massachusetts Institute of Technology
Atmospheric Composition	TL	A.O.C. Nier	University of Minnesota
	TM	M.B. McElroy	Harvard University
	TM	N.W. Spencer	NASA-GSFC
Inorganic Chemical Investigations	TL	P. Toulmin, III	US Geological Survey
	TM	A.K. Baird	Pomona College
	TM	K. Keil	Universtity of New Mexico
	TM	H.J. Rose	US Geological Survey

Experiment	Experiment Personnel		Affiliation
	TM	B. C. Clark	Martin-Marietta Aerospace Corporation
Ionospheric Properties	TL	A.O.C. Nier	University of Minnesota
	TM	W.B. Hanson	University of Texas, Dallas
	TM	N.W. Spencer	NASA-GSFC

INTELSAT IV A F-1

Launch Vehicle – Same as Intelsat IV.

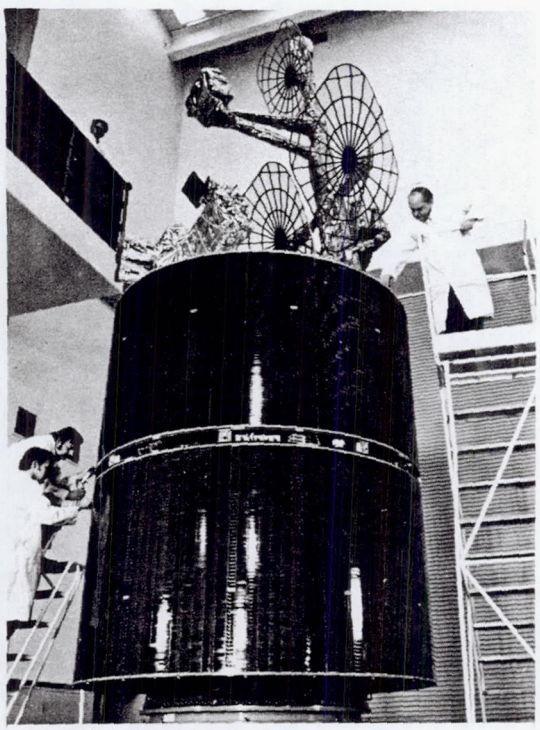
Spacecraft Description – Main body was similar to Intelsat IV, with solar arrays providing 600 watts. Antenna array changed for increased capacity (see payload description). Overall height 267 inches. Weight at launch, about 3,300 pounds; in orbit, about 1,750 pounds.

Project Objectives – Provide increased capacity for Intelsat global communications network.

Spacecraft Payload – A 20-transponder system employing frequency re-use and new antennas provided about twice the capacity of Intelsat IV. Mechanically despun platform supported twin 53-inch dish transmit antennas. The receive antenna used two sets of feed horns working in conjunction with a third dish reflector. Each transponder had a bandwidth of 36 MHz.

Project Results – Intelsat IVA Flight I was launched from Kennedy Space Center, Florida on September 25, 1975. It was placed on station at 21° W. longitude over the Atlantic Ocean on December 25, 1975.

Major Participants – Spacecraft management, Comsat Corp. for Intelsat Organization; spacecraft prime contractor, Hughes Aircraft Co.; launch vehicle management, NASA Lewis Research Center; launch vehicle prime contractor, General Dynamics/Convair; apogee motor, Aerojet-General. Major suppliers from ten countries made up the international contractor team.



Intelsat IV F-1, the first in a series of improved COMSAT communications satellites, was launched on September 25, 1975. It doubled the capacity for data received on the previous system.

EXPLORER 54-
Atmosphere Explorer D

Launch Vehicle – Two-stage Delta 2910, 116 feet long, 8 feet in diameter. McDonnell Douglas modified Thor booster first stage with nine strap-on Thiokol solid fuel rocket motors and a TRW Inc. liquid fuel pressure fed second stage.

Spacecraft Description – Drum-shaped, 16-sided polyhedron, 53.2 inches in diameter and 45 inches high. Consisted of two shells, inner and outer, with solar cells, telemetry antennas and viewing ports on outer shell. Inner shell held 12 scientific instruments and four engineering measurements (212 pounds) electronic packages, attitude, control system and hydrazine thruster subsystem. Solar cells on the exterior shell and redundant nickel-cadmium batteries provided 120 watts of power. Total weight was 1,488 pounds.

Project Objectives – Continue work of sampling upper atmosphere begun by predecessor, AE-C, sampling regions over both poles that AE-C could not reach. Atmosphere Explorer D was called Explorer 54 in orbit.

Spacecraft Payload – Twelve instruments, an ultraviolet photometer, a cylindrical electrostatic probe, atmosphere density accelerometer, photoelectron spectrometer, retarding potential analyzer, visual airglow photometer, solar extreme ultraviolet spectrophotometer, magnetic ion mass spectrometer, low-energy electron spectrometer, open-source neutral mass spectrometer, neutral atmosphere composition spectrometer, and a neutral atmosphere temperature spectrometer.

Project Results – Atmosphere Explorer D (Explorer 54) was launched Oct. 6, 1975 from NASA's Western Test Range at Lompoc, California, into a polar orbit of about 2400 by 100 miles.

Major Participants – Overall direction by NASA's Office of Space Science. Goddard Space Flight Center provided spacecraft and launch vehicle management. Launch operations by Kennedy Space Center. RCA Inc. was spacecraft prime contractor. McDonnell Douglas Astronautics Co. built the launch vehicle.

Key Spacecraft Personnel		Affiliation
PM	D.W. Grimes	NASA-GSFC
PS	N.W. Spencer	NASA-GSFC
MG	F.W. Gaetano	NASA Headquarters
SC	E.R. Schmerling	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Cyl. Electrostatic Probe	PI	L.H. Brace	NASA-GSFC
	OI	R.F. Theis	NASA-GSFC
	OI	A. Dalgarno	Smithsonian Atmospheric Observatory
Tri-Axis Occultation System	PI	K.S.W. Champion	USAF Geophysical Laboratory
	OI	F.A. Marcos	USAF Geophysical Laboratory
Photoelectric Spectrum	PI	J.P. Doering	Johns Hopkins University
	OI	C.O. Bostrom	Applied Physics Laboratory
	OI	J.C. Armstrong	
Retard Potl. Analyzer	PI	W.B. Hanson	University of Texas, Dallas
	OI	D.R. Zuccaro	University of Texas, Dallas
	OI	S. Sanatani	University of Texas, Dallas
	OI	C.R. Lippencott	University of Texas, Dallas
Solar EUV Flux	PI	D.F. Heath	NASA-GSFC
	OI	J.F. Osantowski	NASA-GSFC
Solar EUV Spectrometer	PI	H.E. Hinteregger	USAF Geophysical Laboratory
	OI	D.E. Bedo	USAF Geophysical Laboratory
	OI	L.A. Hall	USAF Geophysical Laboratory
	OI	C.W. Chagnon	USAF Geophysical Laboratory
	OI	J.E. Manson	USAF Geophysical Laboratory
Open Source Spectrometer	PI	A.O.C. Nier	University of Minnesota
	OI	W.E. Potter	University of Minnesota
	OI	K. Mauersberger	University of Minnesota
Neutrino Atmospheric Composition Experiment (NACE)	OI	C. A. Reber	NASA-GSFC
	OI	G.R. Carignan	University of Michigan
	PI	A.E. Hedin	NASA-GSFC
Neutrino Atmospheric Temperature Experiment (NATE)	PI	N.W. Spencer	NASA-GSFC
	OI	G.R. Carignan	University of Michigan
	OI	H.B. Niemann	NASA-GSFC
Magnetic Ion Mass Spectrometer	PI	J.H. Hoffman	University of Texas, Dallas
	OI	E.E. Ferguson	NOAA-ERL
	OI	W.B. Hanson	University of Texas, Dallas
	OI	C.R. Lippencott	University of Texas, Dallas

Experiment	Experiment Personnel		Affiliation
UV Nitric Oxide Experiment	PI	C.A. Barth	University of Colorado
	OI	D.W. Rusch	University of Colorado
	OI	A.I. Stewart	University of Colorado
Low Energy Electron Experiment	PI	R.A. Hoffman	NASA-GSFC
	OI	D.S. Evans	NOAA-ERL
	OI	J.L. Burch	Southwest Research Institute
Visible Airglow Experiment	PI	P.B. Hays	University of Michigan
	OI	G.G. Shepherd	York University
	OI	G.R. Carignan	University of Michigan
	OI	J.C.G. Walker	Arecibo Observatory
Capacitance Pressure Gauge	PI	C.J. Rice	Aerospace Corporation
Cold Cathode Pressure Gauge	PI	C.J. Rice	Aerospace Corporation
Electric Fields	PI	N.C. Maynard	NASA-GSFC
	OI	T.L. Aggson	NASA-GSFC
	OI	J.P. Heppner	NASA-GSFC
Reflected Gas (MRMU)	PI	J.J. Scialdone	NASA-GSFC
Planetary Atmospheric Composition Test	PI	H.B. Niemann	NASA-GSFC

SMS-C/GOES-A

Launch Vehicle – Delta 2914 – A three-stage Delta with an overall length of approximately 35 meters (116 feet) and a diameter of 2.4 meters (8 feet). The first stage was a modified Thor booster incorporating nine strap-on solid-fuel rocket motors powered by liquid oxygen and liquid hydrocarbon propellants. The second stage was powered by a liquid-fuel pressure-fed engine which was gimbal-mounted to provide pitch and yaw control through second-stage burn. The third stage was a spin-stabilized solid-propellant motor.

Spacecraft Description – Cylindrical main body 106 inches high and 75 inches in diameter. Solar arrays provided 200 watts of power. The spin-stabilized spacecraft weighed about 1,375 pounds at launch, 650 pounds in orbit. Thirty-two-inch magnetometers extended from the end of the cylinder. An apogee kick motor attached to the spacecraft was ejected after synchronous orbit was achieved.

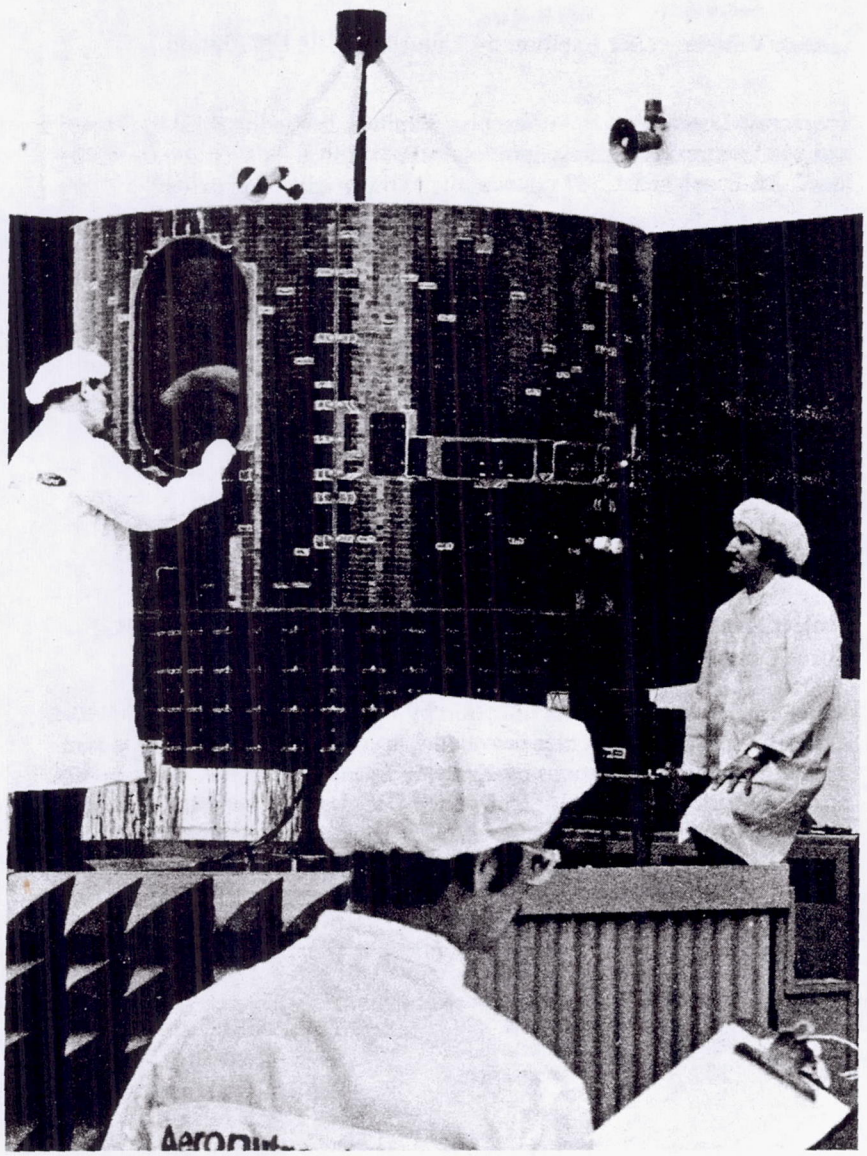
Project Objectives – SMS-C/GOES-A was the first operational satellite in the National Oceanic and Atmospheric Administration's (NOAA) synchronous weather satellite system. It was an outgrowth of two earlier synchronous meteorological satellite research and development flights, SMS-1 (1974) and SMS-2 (1975), which continued to be used as part of the system. NASA procured and launched GOES spacecraft, then turned them over to NOAA for orbital operation. The objective of this mission was to provide improved meteorological data on worldwide weather phenomena for improved forecasting and prediction. The satellite provided pictures of approximately one-quarter of the Earth at 30-minute intervals, day and night. Pictures and data aided scientists in weather detection and prediction, observations of ocean currents, monitoring river water levels, and other meteorological evaluations.

Spacecraft Payload – Visible/infrared spin-scan radiometer provided day and night global weather pictures.

Project Results – GOES A was placed in operation in synchronous orbit after a successful October 16, 1975 launch from Kennedy Space Center, Florida.

Major Participants – Spacecraft management, NASA Goddard Space Flight Center; spacecraft orbital operation, NOAA; spacecraft prime contractor, Aeronutronic Ford Corp.; launch vehicle management, NASA-Goddard; launch vehicle prime contractor, McDonnell Douglas; launch operations, NASA Unmanned Launch Operations, KSC.

Key Spacecraft Personnel		Affiliation
PM	R.H. Pickard	NASA-GSFC
PS	W.E. Shenk	NASA-GSFC
MG	A.J. Cervenka	NASA Headquarters



GOES-A geostationary operational satellite, was designed to transmit clear, sharp photos to receiving stations every 30 minutes for meteorological uses. Two earlier research and development versions were known as Synchronous Meteorological Satellites 1 and 2.

Experiment	Experiment Personnel	Affiliation
V/Iridium Spin-Scan Radiometer (VISSR)	PI Ness Staff OI W.E. Shenk	NOAA-NESS NASA-GSFC
Solar Energetic Particles	PI D.J. Williams OI H.H. Sauer	NOAA-ERL NOAA-ERL
Solar X-ray Monitor	PI D.J. Williams OI R.F. Donnelly	NOAA-ERL NOAA-ERL
Biaxial Fluxgate Magnetometer	PI D.J. Williams OT J.N. Barfield	NOAA-ERL NOAA-ERL
Meteorological Data Collection System	CO J. Puerner PI Ness Staff	NOAA-NESS NOAA-NESS

EXPLORER 55-
Atmosphere Explorer E

Launch Vehicle – (See Explorer 54 Launch Vehicle Description.)

Spacecraft Description – Atmosphere Explorer E was the third in the series and was identical to Atmosphere Explorer D with the exception of the payload. AE-E weighed 1,587 pounds; the extra weight was payload.

Project Objectives – Generally the same as Atmosphere Explorer D with the added task of measuring ozone in the upper atmosphere with an eye toward possible depletion from man-made causes.

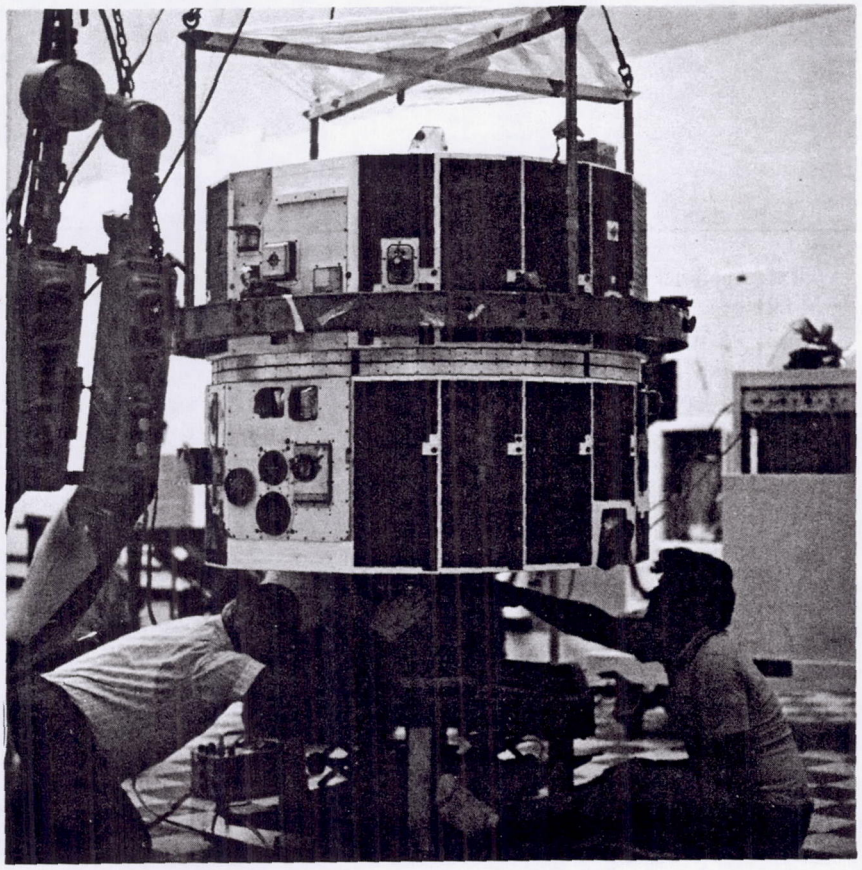
Spacecraft Payload – Twelve instruments. Cylindrical electrostatic probes, atmospheric density accelerometer, photoelectron spectrometer, positive ion mass spectrometer, airglow photometer, solar extreme ultraviolet spectrophotometer, open source neutral mass spectrometer, neutral atmosphere composition instrument, neutral temperature mass spectrometer, backscatter ultraviolet spectrometer, planar ion trap, and solar extreme ultraviolet photometer.

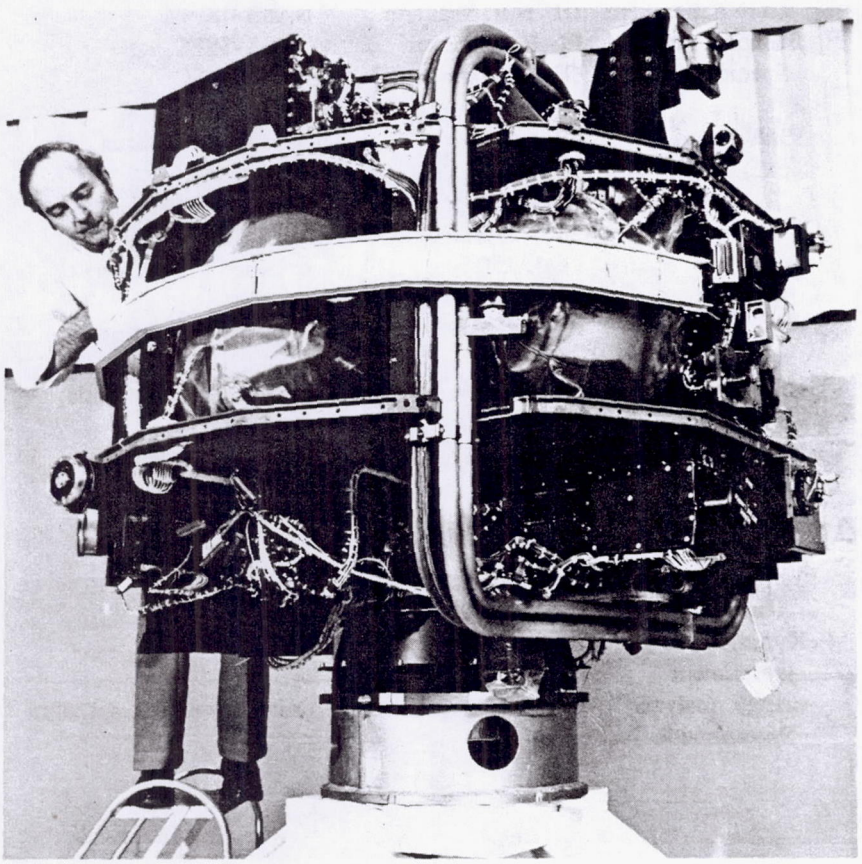
Project Results – Atmosphere Explorer E was launched from Kennedy Space Center on November 20, 1975.

Major Participants – Overall direction by NASA's Office of Space Science. Goddard Space Flight Center provided spacecraft and launch vehicle management. Launch operations by Kennedy Space Center. RCA Inc. was spacecraft prime contractor. McDonnell Douglas Astronautics Co. built the launch vehicle.

Key Spacecraft Personnel		Affiliation
PM	D. Grimes	NASA-GSFC
PS	N.W. Spencer	NASA-GSFC
MG	F.W. Gaetano	NASA Headquarters
SC	E.R. Schmerling	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Cep.-Cyl. Electrostatic Probe	PI	L.H. Brace	NASA-GSFC
	OI	R.F. Theis	NASA-GSFC
	OI	A. Dalgarno	SAO
Tri-Axis-Acculta-tion System	PI	K.S.W. Champion	USAF Geophysics Laboratory
	OI	F.A. Marcos	USAF Geophysics Laboratory
Pes.-Photoelectric Spectrometer	PI	J.P. Doering	Johns Hopkins University
	OI	C.O. Bostrom	Applied Physics Laboratory
RPA-Retarding Potent Analyzer	PI	W.B. Hanson	University of Texas, Dallas
	OI	D.R. Zuccaro	University of Texas, Dallas
	OI	S. Sanatani	University of Texas, Dallas
	OI	C.R. Lippencott	University of Texas, Dallas





Atmosphere Explorer E/Explorer 55 is prepared for launch on November 20, 1975. Third in a series of maneuverable unmanned spacecraft to study upper atmosphere including protective ozone layer above the equator.

Experiment	Experiment Personnel		Affiliation
Extreme Solar UV Monitor	PI	D.F. Heath	NASA-GSFC
	OI	J.F. Osantowski	NASA-GSFC
Solar EUV Spectrometer	PI	H.F. Hinteregger	USAF Geophysics Laboratory
	OI	D.E. Bedo	USAF Geophysics Laboratory
	OI	L.A. Hall	USAF Geophysics Laboratory
	OI	J.E. Manson	USAF Geophysics Laboratory
	OI	C.W. Chagnon	USAF Geophysics Laboratory
Open Source Spectrometer	PI	A.O.C. Nier	University of Minnesota
	OI	W.E. Potter	University of Minnesota
	OI	K. Mauersberger	University of Minnesota
Neutrino Atmosphere Composition Experiment	OI	C.A. Reber	NASA-GSFC
	OI	G.R. Carignan	University of Michigan
	PI	A.E. Hedin	NASA-GSFC
Neutrino Atmospheric Temperature Experiment	PI	N.W. Spencer	NASA-GSFC
	OI	G.R. Carignan	University of Michigan
	OI	H.B. Neimann	NASA-GSFC
Bennett Ion Mass Spectrometer	PI	H.C. Brinton	NASA-GSFC
	OI	M.W. Pharo, III	NASA-GSFC
	OI	H.A. Taylor, Jr.	NASA-GSFC
Visible Airglow Experiment	PI	P.B. Hays	University of Michigan
	OI	G.G. Shepherd	York University
	OI	G.R. Carignan	University of Michigan
	OI	J.C.G. Walker	Arecibo Observatory
Capacitance Pressure Gauge	PI	C.J. Rice	Aerospace Corporation
Cold Cathode Pressure Gauge	PI	C.J. Rice	Aerospace Corporation
HE + Hydr. Airglow	PI	C.S. Bowyer	University of California, Berkeley
Nitric Oxide Airglow	PI	C.A. Barth	University of Colorado
Backscatter UV Spectrum	PI	D.F. Heath	NASA-GSFC
Temperature Alarm (TAL)	PI	P. Caruso	NASA-GSFC
Radiation Damage Experiment	PI	R.A. Cliff	NASA-GSFC
Energy Analyzer Spectrometer Test	PI	J.H. Hoffman	University of Texas, Dallas

RCA SATCOM-A

Launch Vehicle – Model 3914, new three-stage Delta with nine Castor IV solid-propellant strap-on motors. Each Castor IV was 36.6 feet long and 40 inches in diameter and each generated 74,000 pounds of thrust.

Spacecraft Description – RCA-Satcom A weighed 1,913 pounds at launch and 1,021 pounds on station after firing its apogee kick motor. The satellite was box-shaped, 5.3 feet by 4.1 feet by 4.1 feet. Two rectangular solar panels extended from the spacecraft on short booms. The 75.5 square feet of silicon solar cells were continuously oriented toward the sun to provide 770 watts of power. It was three-axis stabilized and earth-oriented.

Project Objectives – RCA Inc. took the first step in establishing a privately owned domestic communications satellite system with launch of RCA-Satcom-A. It was the first of three planned satellites in geostationary orbit to serve all 50 United States with television, voice channels and high-speed transmissions. This mission provided 24 communication channels that relayed voice, video and data communications traffic to all 50 United States. Each of the 24 channels was designed to carry 1,000 voice circuits, one FM/color TV transmission or 64 million bits per second of computer data.

Spacecraft Payload – Transponder and cross-polarized antenna system providing 24 channels in the 4 and 6 GHz common carrier bands.

Project Results – Launched from Cape Canaveral, Fla., aboard a Delta launch vehicle Dec. 13, 1975. Reached geostationary orbit on seventh apogee.

Major Participants – RCA Astro-Electronics Division built the spacecraft. System management was by RCA Global Communications Inc. and RCA Alaska Communications Inc. NASA's Goddard Space Flight Center, Greenbelt, Md., managed the Delta launch vehicle. McDonnell Douglas Astronautics Co., Huntington Beach, Calif., built the launch vehicle.



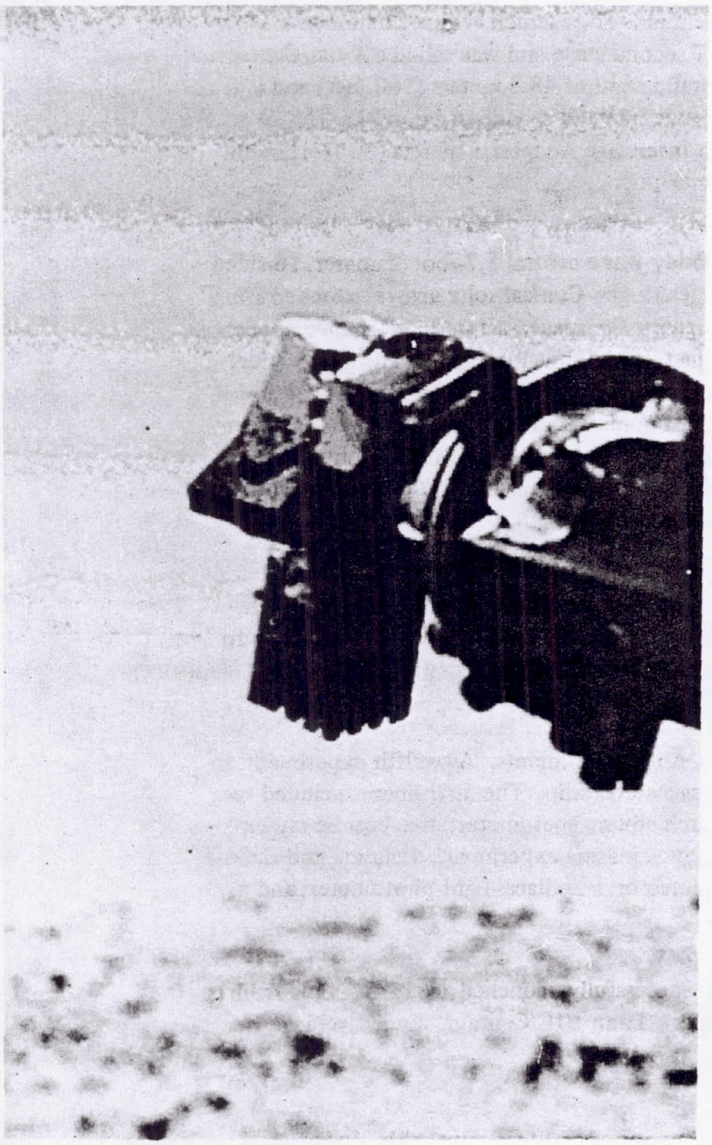
RCA-A, first RCA domestic communications satellite, launched by Delta 118 on December 13, 1975, was placed into a geosynchronous orbit. The government was reimbursed for launch costs.

1975

On August 9, 1976, this picture was transmitted from Mars over a distance of some 225 million miles. It shows the surface sampler in operation.

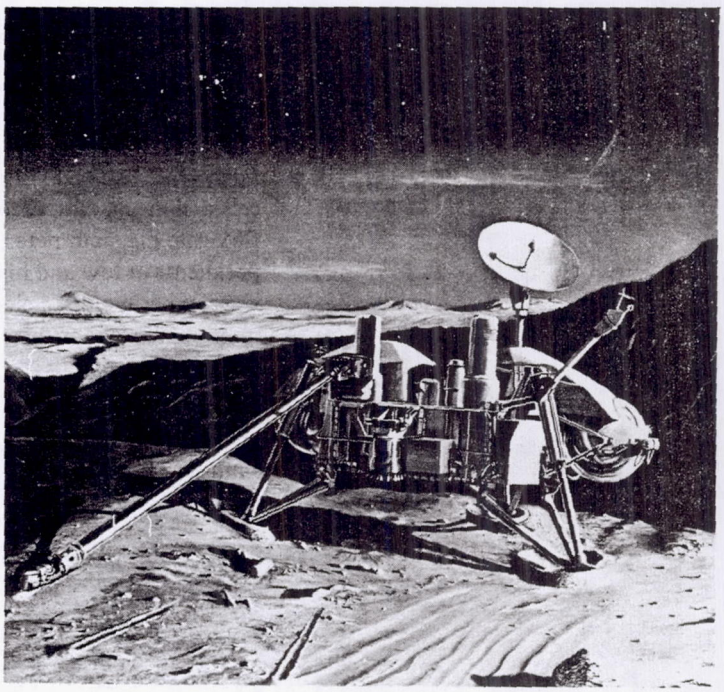
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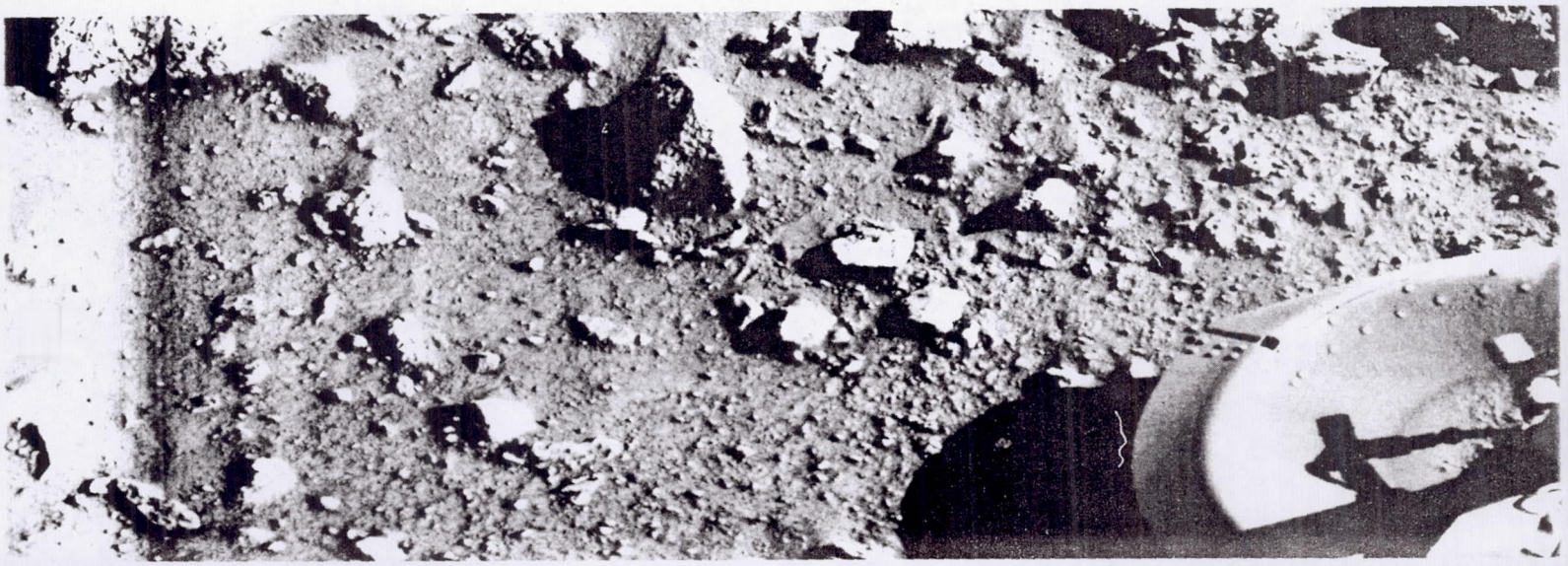
1976



Viking-A returned the picture of Martian rocks, sand, or dust. The large rock in the center is about 4 inches across. Spacecraft's footpad in the foreground.

Artist's conception of Viking lander on the surface of Mars.





HELIOS-B

Launch Vehicle: Titan IIIE/Centaur–The Launch vehicle combined a Titan IIIE booster and Centaur D-1T second stage and was called a Titan/Centaur. The Titan/Centaur had an overall height of 48.8 meters (160 feet) and a total liftoff weight of 64,000 kilograms (1.4 million pounds). The two vehicles were connected by an Interstage Adapter 3 meters (10 feet) in diameter and 2.9 meters (9.5 feet) long.

Spacecraft Description–Main body was a central 5.7-foot diameter, 16-sided experiment compartment, 1.8 feet high. Conical solar arrays extended from each end of the compartment, giving the spacecraft its spool-shaped appearance. Spool height was seven feet; an antenna mast added another 6.7 feet to the vehicle's height. The two conical arrays provided 240 watts of power at aphelion. Two magnetometer booms with a tip-to-tip length of 105 feet were deployed from the sides of the main body. The central compartment housed eleven experiments with a combined weight of 158 pounds. Total spacecraft weight was 826 pounds in orbit.

Project Objectives–Study the Sun from an orbit nearer the center of the solar system than any previously attempted. Helios-B's closest approach to the sun–27 million miles–this occurs every 186 days.

Spacecraft Payload–Eleven scientific instruments. A twelfth experiment, in celestial mechanics, used the spacecraft radio. The instrument included two flux gate magnetometers; a search coil magnetometer; two cosmic ray experiments at low and high energy; a plasma experiment, a plasma and radio wave experiment; an electron detector; a zodiacal light photometer; and a micrometeoroid analyzer.

Project Results–Helios-B was successfully launched at 12:34 a.m. from Cape Canaveral, Florida, aboard a Titan IIIE/Centaur, launch vehicle, on January 15, 1976.

Major Participants — Responsibility for the joint U.S.-German program was shared by NASA and German Ministry for Research and Technology. Spacecraft prime contractor, Messerschmitt-Bolkow-Blohm, GmBH; launch operations, NASA Kennedy Space Center; Titan launch vehicle prime contractor, Martin Marietta Aerospace; Centaur phase contractor, General Dynamics/Convair; Delta phase kick motor; McDonnell-Douglas, USAF Space and Missile Systems Org., LeRC launch vehicle management.

Key Spacecraft Personnel		Affiliation
PM	A. Kutzer	Gesellschaft Fur Weltraumforschung
PM	G. W. Ousley	NASA-GSFC
PS	H. Porsche	DFVLR
PS	J. H. Trainor	NASA-GSFC
CO	K. Kasmeier	BWF
SC	A. G. Opp	NASA Headquarters
MG	E. J. Montoya	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Triaxis Fluxgate Magnetometer	PI	F. M. Neubauer	Braunschweig Technical University
	OI	A. Maier	Braunschweig Technical University
Triaxis Fluxgate Magnetometer	PI	N. F. Ness	NASA-GSFC
	OI	F. Mariani	University of Rome
	OI	L. F. Burlaga	NASA-GSFC
	OI	S. C. Cantarano	CNR, Space Plasma Laboratory
Triaxis Search Coil Magnetometer	OI	G. Dehmel	Braunschweig Technical University
	PI	F. M. Neubauer	Braunschweig Technical University
Coarse Wave Spectrum Analyzer	PI	D. A. Gurnett	University of Iowa
	OI	P. J. Kellogg	University of Minnesota
	OI	S. J. Bauer	NASA-GSFC
	OI	R. G. Stone	NASA-GSFC
Fine Wave Spectrum Analyzer	PI	D. A. Gurnett	University of Iowa
	OI	P. J. Kellogg	University of Minnesota
	OI	S. J. Bauer	NASA-GSFC
	OI	R. G. Stone	NASA-GSFC
27Hz-3MHz Radio Wave	PI	D. A. Gurnett	University of Iowa
	OI	P. J. Kellogg	University of Minnesota
	OI	R. R. Weber	NASA-GSFC
	OI	R. G. Stone	NASA-GSFC
1MeV-1GeV CR Prot. + Alpha	PI	H. Kunow	University of Kiel
	OI	G. H. Wibberenz	University of Kiel
	OI	G. Green	University of Kiel
	OI	M. Mueller-Mellin	University of Kiel
	OI	M. Witte	University of Kiel
	OI	H. Hempe	University of Kiel
Cosmic Ray Detectors	PI	J. H. Trainor	NASA-GSFC
	OI	E. C. Roelof	Applied Physics Laboratory
	OI	B. J. Teegarden	NASA-GSFC
	OI	F. B. McDonald	NASA-GSFC
	OI	K. G. McCracken	CSIRO

Experiment	Experiment Personnel		Affiliation
Plasma Detectors	PI	H. R. Rosenbauer	MPI-Aeronomy
	OI	H. Pellkofer	MPI-Extraterrestrial Physics
	OI	J. H. Wolfe	NASA-ARC
Electron Det., 40keV-1MeV	PI	E. Keppler	MPI-Aeronomy
	OI	B. Wilken	MPI-Aeronomy
	OI	D. J. Williams	NOAA-ERL
Zodiacal Light Photometer	PI	C. Leinert	MPI-Astronomie
	OI	E. Pitz	MPI-Astronomie
Micrometeoroid Detector	PI	H. Fechtig	MPI-Nuclear Physics
	OI	J. Weihrauch	MPI-Physics Astrophysics
RF Elect. Fields	PI	D. A. Gurnett	University of Iowa
	OI	S. J. Bauer	NASA-GSFC
	OI	P. J. Kellogg	University of Minnesota
	OI	R. G. Stone	NASA-GSFC
Celestial Mechanics	PI	W. Kundt	University of Hamburg
	OI	W. G. Melbourne	NASA-JPL

COMMUNICATIONS TECHNOLOGY SATELLITE (CTS)

Launch Vehicle – Delta 2914. (See NATO III.)

Spacecraft Description – Main body of the spacecraft was shaped like a cylinder with two flattened sides, 74 inches high and 72 inches across. Housed in the main body was the apogee kick motor. Extending from the sides of the spacecraft were two winglike solar arrays which gave CTS a "wing span" of 55 feet. The arrays provided about 1,250 watts of power to the spacecraft and its payload. CTS was three-axis stabilized by means of a momentum wheel/hydrazine reaction control system. Weight at launch was approximately 1,500 pounds.

Project Objectives – The Communications Technology Satellite was a joint U.S.-Canadian vehicle for demonstrating the benefits to be derived from satellite communications to remote areas where terrestrial communication links are inadequate or nonexistent. The concept, developed by Canada's Department of Communications calls for high (200-watt) levels of transmission power aboard the satellite so that small, relatively inexpensive ground terminals may be used. CTS experiments included broadcasts of a variety of social, cultural, and educational material to a number of remote regions in the North of Canada.

This mission demonstrated the capability of a satellite carrying high-power (200 watts) transmitting equipment operating at high frequencies to broadcast television and voice to small, inexpensive ground stations in remote areas. About 40 experiments used CTS to demonstrate a variety of practical applications for such a capability.

Spacecraft Payload – Basic communications payload was a 200-watt transmitter. The system included two steerable parabolic reflectors and a "spotting beacon" and its antenna.

Project Results – CTS was launched January 17, 1976 from Kennedy Space Center and subsequently positioned at its "operating station" in synchronous equatorial orbit at 116 degrees west longitude.

Major Participants –Canada's Department of Communications had overall responsibility for the CTS program. NASA's Lewis Research Center was responsible for U.S. commitments to the joint venture. Spacecraft builder: Canadian Communications Research Centre; 200-watt TWT-transmitter-power supply: NASA-Lewis, with procurements from Litton Industries and TRW; launch vehicle management: Goddard Space Flight Center; launch vehicle prime contractor: McDonnell Douglas.

Key Spacecraft Personnel		Affiliation
MG	I. Paghis	Communications Research Centre
PM	J. N. Barry	Communications Research Centre
PS	A. S. Brown	Communications Research Centre
MG	W. M. Lew, Jr.	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Super HF (12+14 GHz) Communications	PI	J. W. B. Day	Communications Research Centre
Solar Array Tech. Experiment	PI	F. R. Vigneron	Communications Research Centre
Attitude Control System Experiment	PI	F. R. Vigneron	Communications Research Centre
Canadian Communications Experiments	CO	N. G. Davies	Department of Communications, Canada
	CO	A. A. Whalen	NASA-GSFC
	CO	H. E. Hudson	Stanford University
	PI	Kerr	Unknown
U.S. User Experiments	PI	Donoughe	Unknown

INTELSAT IV A
Flight 2

Launch Vehicle – Atlas Centaur. (See COMSTAR Launch Vehicle description.)

Spacecraft Description – Drum-shaped spin-stabilized main body, 111 inches high and 94 inches in diameter. Antenna array brought total height to 267 inches. Solar arrays covering the sides of the main body provided approximately 600 watts of power. Solid propellant apogee motor mounted in the base of the cylinder provided 10,000 pounds of thrust. Antennas were mounted on a despun platform atop the cylinder. Weight at launch was about 3,300 pounds, in orbit, 1,750 pounds.

Project Objectives – Provided increased telecommunications capacity for Intelsat's global network. Intelsat IVA's were to serve as replenishments as basic Intelsat IV's wore out.

Spacecraft Payload – A 20-transponder system employing frequency reuse and new antennas provided at least 6,250 telephone circuits and two TV channels. Mechanically despun platform supported twin 53-inch dish transmit antennas. The receive antenna used two sets of feedhorns working in conjunction with a third dish reflector. Each transponder had a bandwidth of 36 MHz.

Project Objectives – Provided increased telecommunications capacity for Intelsat's global network. Intelsat IVA's were to serve as replenishments as basic Intelsat IV's wore out.

Major Participants – Spacecraft manager, COMSAT Corp. for Intelsat; spacecraft prime contractor, Hughes Aircraft Co.; launch management, NASA Lewis Research Center; launch vehicle prime contractor, General Dynamics/Convair.

MARISAT-A, B, and C

Launch Vehicle – Straight-Eight Delta. First stage thrust was 205,000 pounds. Carried nine strap-on solid propellant motors on first stage. Each Castor II solid generated 52,000 pounds of thrust. The second stage produced 9,800 pounds of thrust and was capable of restarting. It used a modified version of the Apollo Lunar Module Descent Engine developed by TRW for the moon-landing program. The third stage used a Thiokol solid motor that generated 14,100 pounds of thrust.

Spacecraft Description – All three Marisat satellites were physically identical with each positioned in geosynchronous orbit to serve different geographical segments of Earth. At liftoff, the Marisats weighed 655 kg (1445 lbs.). The satellite was 231 cm (12-1/2-ft.) with antennas. A cylindrical solar panel, containing approximately 7,000 solar cells, supplied the spacecraft with primary power of 330 watts.

Project Objectives – The maritime industry has long been concerned with improvement of communications. The American Institute of Merchant Shipping estimated that by 1980, the number of vessels of more than 1,600 gross tons on the high seas at any one time would reach 14,000. More than 90-percent of present ship-to-shore communications used archaic "brass key" radiotelegraph technology. Maritime communications satellites were to dramatically change marine communications in the 1980's.

Marisats provided rapid, high-quality communications between ships at sea and home offices. Telephone and Telex messages could be exchanged without fear of interference or delay due to severe weather or ionospheric disturbances that may interrupt conventional radio traffic. Marisats were expected to significantly improve communications of distress, safety, search and rescue, and weather reports.

Spacecraft Payload – Three UHF channels reserved for U.S. government use were provided on each Marisat. These could be activated or deactivated by ground command. In addition, an L- and a C-band channel, each 4 MHz wide, were available. One channel translated ship-to-shore signals from 6 GHz to 4 GHz. The satellite UHF channels for U.S. government use were completely separate from the L- and C-band facilities. Each Marisat had a five-year operating life expectancy.

Project Results –

Marisat-A: Launched from Cape Canaveral on February 19, 1976, began to operate in April from a geosynchronous orbit over the Equator at 5 degrees West longitude. It served maritime traffic in the Atlantic Ocean area.

Marisat-B: Launched June 9, 1976, became operational early in July 1976 to serve the major shipping lanes of the Pacific Ocean. Covering an area of 120 million square miles, Marisat-B was on station just west of Hawaii at 176.5 degrees West longitude.

Marisat-C: Launched from Cape Canaveral on October 14, 1976, was the third and final satellite in the system. It was on station at 73 degrees East longitude over the Indian Ocean. The third satellite initially served only the U.S. Navy; however, it also was an in-orbit backup.

Major Participants – Operated by Comsat General Corp., the Marisats were owned by a consortium of Comsat General (86.29 percent), RCA Global Communications, Inc. (8 percent); Western Union International, Inc. (3.4 percent); and ITT World Communications, Inc. (2.3 percent).

All three Marisats were built for Comsat General Corp. by Hughes Aircraft Co. The Delta Straight-Eight launch vehicles were provided by the McDonnell Douglas Astronautics Co. The Delta project was managed by NASA's Goddard Space Flight Center and the Kennedy Space Flight Center conducted all launch operations. Comsat General reimbursed NASA for all launch and administrative costs. The U.S. Maritime Administration and the U.S. Navy were expected to be the major early users of Marisat; however, the prime purpose of the program was to provide common carrier service to ships of all nations.

RCA-B

Launch Vehicle – Three-stage Delta 3914, new three-stage Delta with nine Castor IV solid-propellant strap-on motors. Each Castor IV was 36.6 feet long and 40 inches in diameter and each generated 74,000 pounds of thrust.

Spacecraft Description – Main structure was box-shaped, 5.3 by 4.1 by 4.1 feet with antennas mounted atop. Two wing-like solar arrays extended from the sides of the structure to provide about 770 watts of power. An apogee kick motor was mounted in the base of the main body. The three-axis stabilized spacecraft weighed about 1,900 pounds at launch, 1,020 pounds in orbit.

Project Objectives – Domestic Comsat to provide voice, video, and data transmission (at rates up to 64 million bits per second) throughout the 50 states.

Spacecraft Payload – Communications system included 24 independent 36-MHz transponders operating in the 6-GHz uplink–4-GHz downlink band. A complex antenna system had as its main feature four fixed parabolic reflectors engineered to provide 12 vertically polarized and 12 horizontally polarized antennas, fed by six feedhorns.

Project Results – RCA-B was launched from Kennedy Space Center on March 26, 1976 and subsequently positioned at 128 degrees West longitude in synchronous orbit.

Major Participants – Systems management, RCA Global Communications, Inc.; Satcom prime contractor, RCA Astro-Electronics Division; launch vehicle management, NASA Goddard Space Flight Center; Delta prime contractor, McDonnell Douglas Astronautics Co.

NATO-IIIA

Launch Vehicle – Delta 2914 – A three-stage Delta with an overall length of approximately 35 meters (116 feet) and a diameter of 2.4 meters (8 feet). The first stage was a modified Thor booster incorporating nine strap-on solid-fuel rocket motors powered by liquid oxygen and liquid hydrocarbon propellants. The second stage was powered by a liquid-fuel pressure-fed engine which was gimbal-mounted to provide pitch and yaw control through second-stage burn. The third stage was a spin-stabilized solid-propellant motor.

Spacecraft Description – Drum shaped, the NATO-IIIA spacecraft was about 2.2 meters (86 inches) in diameter, 2.23 meters (88 inches) long, with an overall length of 3.1 meters (122 inches), including antennas. At launch it weighed 720 kg (1,528 lbs.) and after firing its onboard apogee kick motor to place it in stationary orbit, the weight reduced to 376 kg (830 lbs.).

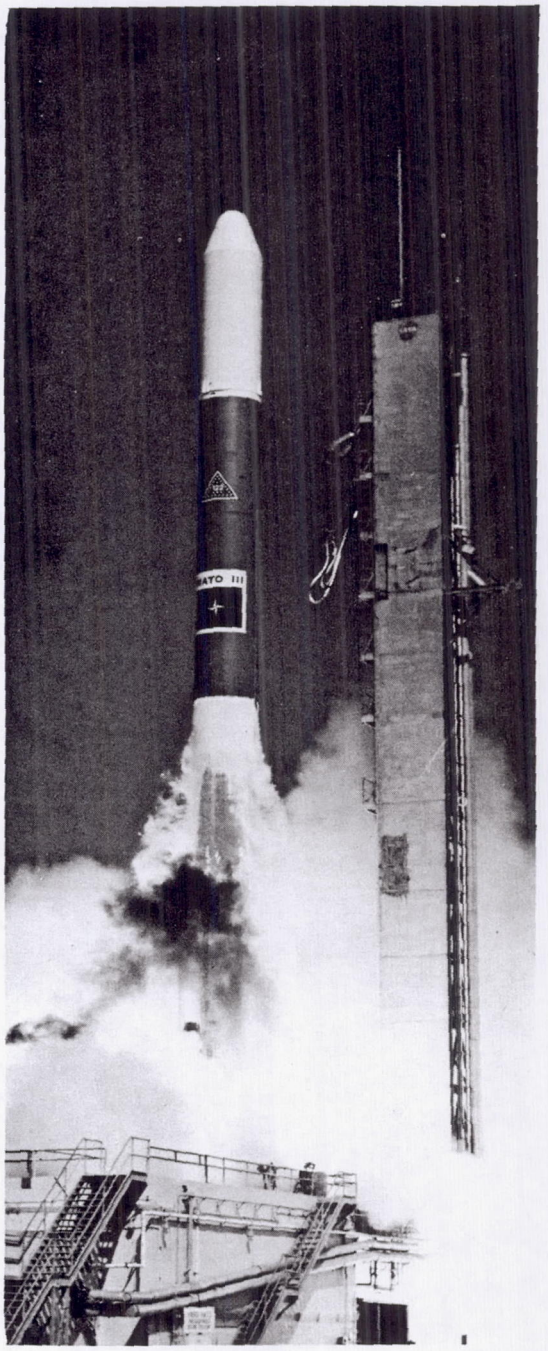
Project Objectives – This was the third in a series of military communications satellites intended to serve the North Atlantic Treaty Organization (NATO). Hundreds of real time communications could be handled by this multi-nation communications system for the NATO alliance countries – Belgium, Canada, Denmark, England, Germany, Iceland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Turkey and the United States.

Offering considerably more power than the two earlier NATO-II satellites, NATO-IIIA provided real-time communication for the nations of the NATO military alliance. The NATO Satcom System Control Center in Belgium, near Supreme Headquarters, Allied Powers, Europe (SHAPE), scheduled and controlled all allied nations communications via NATO-IIIA.

Spacecraft Payload – Operating in the 7 to 8 GHz frequency range, NATO-IIIA used three 20-watt traveling wave tubes with narrow-beam horn antennas permitting high capacity traffic transmission on three channels to and from relatively small ground stations. Unique "nod and tilt" antenna design kept the antennas pointed at the desired coverage zones on the ground. NATO-IIIA received, translated frequency, and retransmitted voice, telegraph, facsimile, and wide-band digital data.

Project Results – Launched April 22, 1976 from the Kennedy Space Center, NATO-IIIA was positioned in a synchronous orbit 36,000 km (22,300 miles) over the Equator, near 18° West longitude, due south of the West coast of Africa.

Major Participants – The NATO-IIIA program was managed by the U.S. Air Force Space and Missile Systems Organization for NATO. The NASA Goddard Space Flight Center and the Kennedy Space Center were responsible for integration and launch operations. Aeronutronic-Ford Corp. produced the satellite and the McDonnell Douglas Astronautics Co. provided the Delta launch vehicle.



NATO III-A, the first in a series of military communications satellites to serve the North Atlantic Treaty Organization, was successfully launched on April 22, 1976.

LAGEOS

Launch Vehicle – Delta 2913.

Spacecraft Description – Lageos was a solid, spherical passive satellite with no moving parts or electronic components. The basic aluminum sphere with a solid brass core was 60 centimeters 24 inches in diameter and it weighed 411 kilograms (903 pounds). It carried an array of 426 prisms, called cube-corner retroreflectors, giving it the dimpled appearance of a golf ball. Retroreflectors were three-dimensional prisms that reflected the laser beams back to their source, regardless of the angle at which it was received. Lageos retroreflectors were made of high optical quality fused silica (a synthetic quartz).

Lageos acted as a very stable reflector for the Earth based laser signals. Measuring the transit time to and from the spacecraft permitted extremely accurate measurements of changes in the Earth's crust (as small as 0.8 inch).

Project Objectives – Lageos mission objectives were to provide a reference point for laser ranging experiments such as: the monitoring of motion of the tectonic plates, the description of the time varying behavior of the Earth's polar positions, the maintenance of geodetic reference systems, and the more accurate determination of universal time. Lageos was the first satellite in the solid-Earth dynamics portion of the NASA Earth and Ocean Dynamics Applications Program (EODAP).

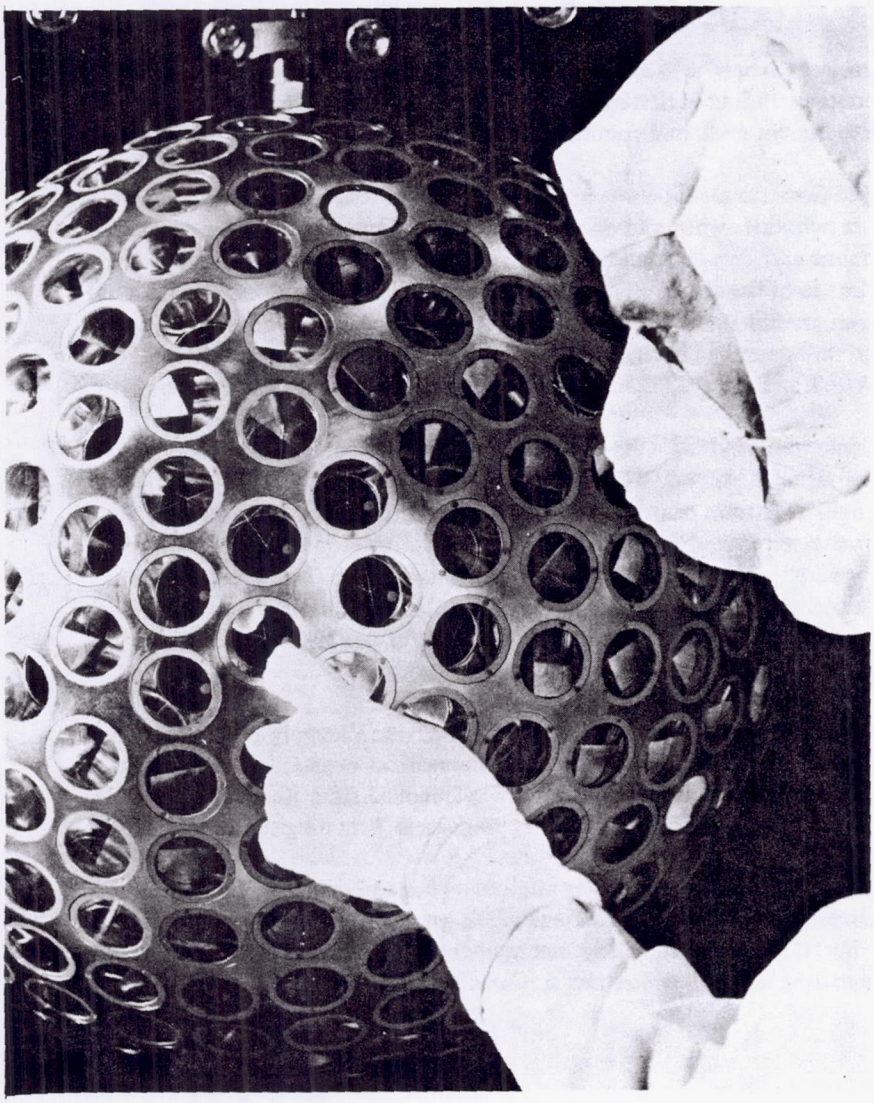
Spacecraft Payload – Lageos was a passive reflector satellite consisting of 426 retroreflectors each 3.8 cm (1.5 in.) in diameter.

Project Results – The Lageos spacecraft was launched from the Western Test Range at Vandenberg Air Force Base, Lompoc, Calif. on May 4, 1976. It was launched by a Delta 2914 three-stage, thrust-augmented launch vehicle into a near circular orbit of 5940 kilometers (3,691 statute miles) apogee and 5845 km (3,632 statute miles) perigee. Inclination of the orbit was 109.8 degrees with an orbit period of 225.5 minutes.

Major Participants – Lageos was part of the Earth and Ocean Dynamics Application Program conducted by the NASA Headquarters Office of Applications. NASA's Marshall Space Flight Center had management responsibility for the design, development, and launch of the satellite. NASA's Goddard Space Flight Center had responsibility for the launch vehicle and the Kennedy Space Flight Center conducted the Lageos launch operations at the Western Test Range at Vandenberg Air Force Base in California. Satellite integration/assembly plus technical and scientific support were provided by the Bendix Corp., Ann Arbor, Michigan. The Perkin-Elmer Corp., Norwalk, Connecticut produced the laser retroreflectors. McDonnell-Douglas Corp., Huntington Beach, Calif. built the Delta launch vehicle. Additional technical and scientific support was provided by the Smithsonian Astrophysical Observatory, Cambridge, Massachusetts.

Key Spacecraft Personnel		Affiliation
PM	C. W. Johnson	NASA-MSFC
PM	C. C. Stephanides	NASA-GSFC
MG	C. J. Finley	NASA Headquarters
PS	D. E. Smith	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Laser System	PI	C. C. Stephanides	NASA-GSFC
	OI	H. H. Plotkin	NASA-GSFC



Laser Geodynamic Satellite (LAGEOS) is tested at the NASA Goddard Space Flight Center. The project was to improve measurements of the Earth's motions and help understand earthquakes.

COMSTAR 1 and 2

Launch Vehicle – Atlas Centaur. The Atlas/Centaur, standing approximately 40.8 meters (134 feet) high, consisted of an Atlas SLV-3D booster and Centaur D-1A second stage. The Atlas booster developed 1,920 kilonewtons (431,300 lb.) of thrust at liftoff using two 822,920-newton (185,000) thrust booster engines, one 266,890-N (60,000 lb.) thrust sustainer engine and two vernier engines developing 2,890 N (650 lb.) thrust each. The two RL-10 engines on Centaur produced a total of 133,450 N (30,000 lb.) thrust. Both the Atlas and the Centaur were 3.048 m (10 ft.) in diameter.

Spacecraft Description – Cylindrical main body was approximately 9-1/2 feet high, 8 feet in diameter; antennas atop the main body brought total spacecraft height to 20 feet. Solar arrays around the cylinder provided more than 600 watts of power. An apogee motor mounted in the base of the cylinder drove the spacecraft to its final orbit. Weight at launch was about 3,300 pounds; in orbit, about 1,800 pounds.

Project Objectives – Establish a communications satellite system serving the contiguous United States, Hawaii, Alaska and Puerto Rico. A secondary experiment evaluated communications at 19 and 28 GHz.

The Comstar satellites were part of the U.S. domestic communications satellite network owned and operated by Comsat General Corp. American Telephone and Telegraph and General Telephone and Electronics were to share the use of the satellites, each integrating satellite communications with its own ground facilities. A three-satellite system was planned in orbit, and a ground spare had been ordered. A network of seven ground stations, four AT&T and three GTE, made up the terrestrial segment of the system.

Spacecraft Payload – Twenty-four transponder communications systems operating in the 4-6 GHz range provided approximately 14,400 telephone circuits. Twelve of the transponders were horizontally polarized; the other twelve were vertically polarized. Two reflectors atop the spacecraft were faced with large flat screens to achieve polarization. Two groups of horns provided spot beam coverage for Hawaii, Alaska, and Puerto Rico. The antenna array also included a pair of horns for the 19-28 GHz evaluation experiments.

Project Results – Comstar 1 was launched from Kennedy Space Center on May 13, 1976 and placed in synchronous orbit over the Equator at 128 degrees West longitude; Comstar 2 was launched from Kennedy Space Center on July 22, 1976 and placed at 94 degrees West longitude.

Major Participants – Comstar satellite owner and operator, Comsat General Corp.; principal users, AT&T and GTE; spacecraft prime contractor, Hughes Aircraft Co.; launch vehicle management, NASA Lewis Research Center; launch vehicle prime contractor, General Dynamics.

PALAPA-A

Launch Vehicle – Delta 2914.

Spacecraft Description – Identical to the Canadian Anik and the Western Union's WESTAR satellites with the exception of the antenna which had been modified to provide optimum illumination of the Indonesian landmass.

Launch weight of the spacecraft was 575 kilograms (1,267 pounds), including the apogee kick motor which weighed 293 kilograms (645 pounds).

Project Objectives – A 600-year-old dream of national unity became a reality with the operation of the Palapa-A communications satellite. It linked 3,000 inhabited islands among the 13,000 in the Indonesian Archipelago with instantaneous telephone, radio, TV, Telex, and data communications. The name for the satellite came from a 14th century prime minister's vow not to eat the then popular delicacy, palapa, until the whole of Indonesia was united.

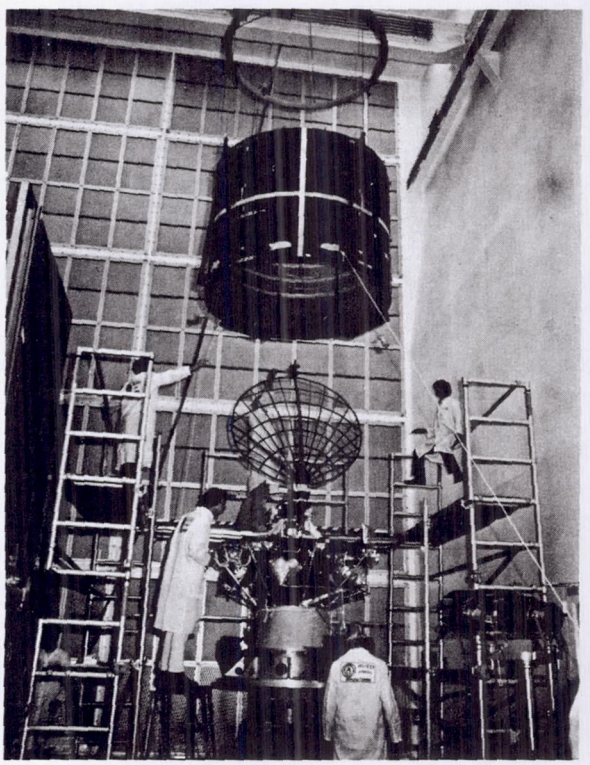
Successful operation of the Palapa series of communications satellites made Indonesia the first Southeast Asian nation to operate its own telecommunications satellite system. Indonesian officials believed that this satellite system would enable the island nation to triple its telephone service by 1978. In 1976, the country had about 250,000 telephones, mostly in urban areas on Sumatra, Java, Bali, Kalimontan, Sulawesi and Irian Jaya. Palapa was expected to increase the number of telephones to over 650,000 in two years. In addition to the telephone circuits, Palapa also provided telegraph, data, radio, television, and Telex capabilities never before available to the nation.

Spacecraft Payload – The 12-transponder satellite had an average capacity of 4,000 voice circuits or 12 simultaneous color television channels. It measured 3.7 meters (11 feet) in height including the antenna and 1.9 meters (6.2 feet) in diameter. The antenna was a shaped-beam, solar-transparent 1.5 meter (4.8 feet) diameter parabolic dish.

Project Results – Launched on July 8, 1976 by NASA from Cape Canaveral, Florida, Palapa-A was in a synchronous orbit 35,800 kilometers (22,300 miles) above the Equator. The Delta rocket injected the satellite into a transfer orbit having an apogee of 36,323 km (22,570 miles), perigee of 230 km (150 miles), and an inclination at the Equator of 24.66 degrees. It was placed into operation on August 17, 1976 from its on-station position at 83 degrees East longitude.

Major Participants – NASA Headquarters administered the Palapa program for the government of Indonesia. NASA project management for the Palapa spacecraft and the Delta launch vehicle were provided by the Goddard Space Flight Center with the Kennedy Space Center responsible for the launch. The satellite was designed and built by the Hughes Aircraft Company. Aeronutronic Ford Corp. and International Telephone and Telegraph built 15 Earth stations to complete the ground system controlled and operated by Perumtel, the Indonesian government-owned and operated telecommunications company.

Palapa-A, Indonesia's communications satellite being tested and launched. It was designed to give some 3,000 inhabited islands, among 13,000 islands in the Indonesian archipelago, instantaneous communications.



1976

ITOS H/NOAA 5

Launch Vehicle – Delta 2310. Two stage Delta, model 2310, three solid propellant rockets with liftoff thrust of 286,500 pounds. The vehicle was 116 feet in height, including its shroud.

Spacecraft Description – Box-shaped main body was approximately 40 by 40 by 54 inches with three solar panels attached to one end of the structure. The three-axis stabilized satellite weighed about 750 pounds.

Project Objectives – The National Oceanic and Atmospheric Administration managed and operated the basic U.S. weather satellites, called NOAA's in orbit, which provide daily cloud-cover pictures and other information for worldwide weather forecasting. Development of the series began in the late 1950's. From 1960 to 1965, the satellites were called TIROS, for Television Infrared Observation Satellite. Ten of these were orbited. From 1966 to 1969 when the satellites were declared operational, they were known as TOS, for TIROS Operational Satellite, or as ESSA, for the Environmental Science Services Administration, which managed the program in that period. Nine were orbited. In 1970, a second generation satellite, known as ITOS, for Improved TOS, was introduced. The satellites were given an ITOS letter designation before launch and a NOAA number designation in orbit.

Operational weather satellites provided images, temperature and moisture data, solar information, and other data for use in assembling day and night global weather information.

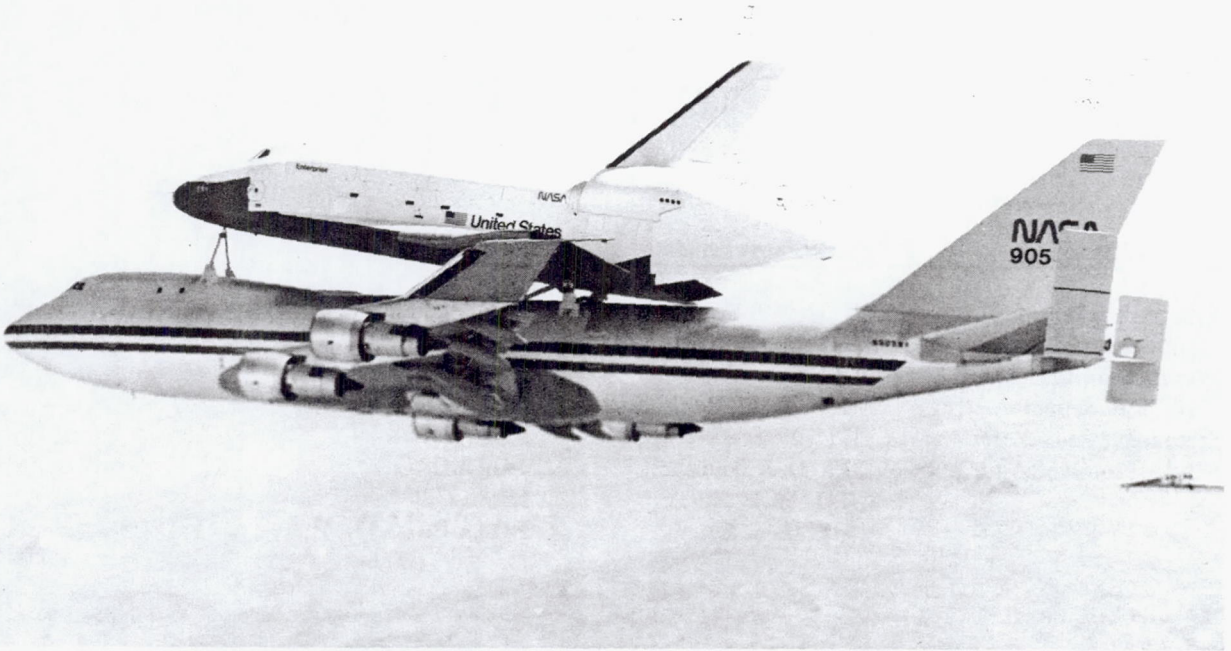
Spacecraft Payload – Radiometric imaging system operated in the visible and the infrared spectrum. Instruments included very high resolution radiometers, vertical temperature profile radiometers, scanning radiometers, and a solar proton monitor.

Project Results – NOAA 5 was launched July 29, 1976 by NASA from the Western Test Range in California and placed in a 820-n.m. near-polar orbit.

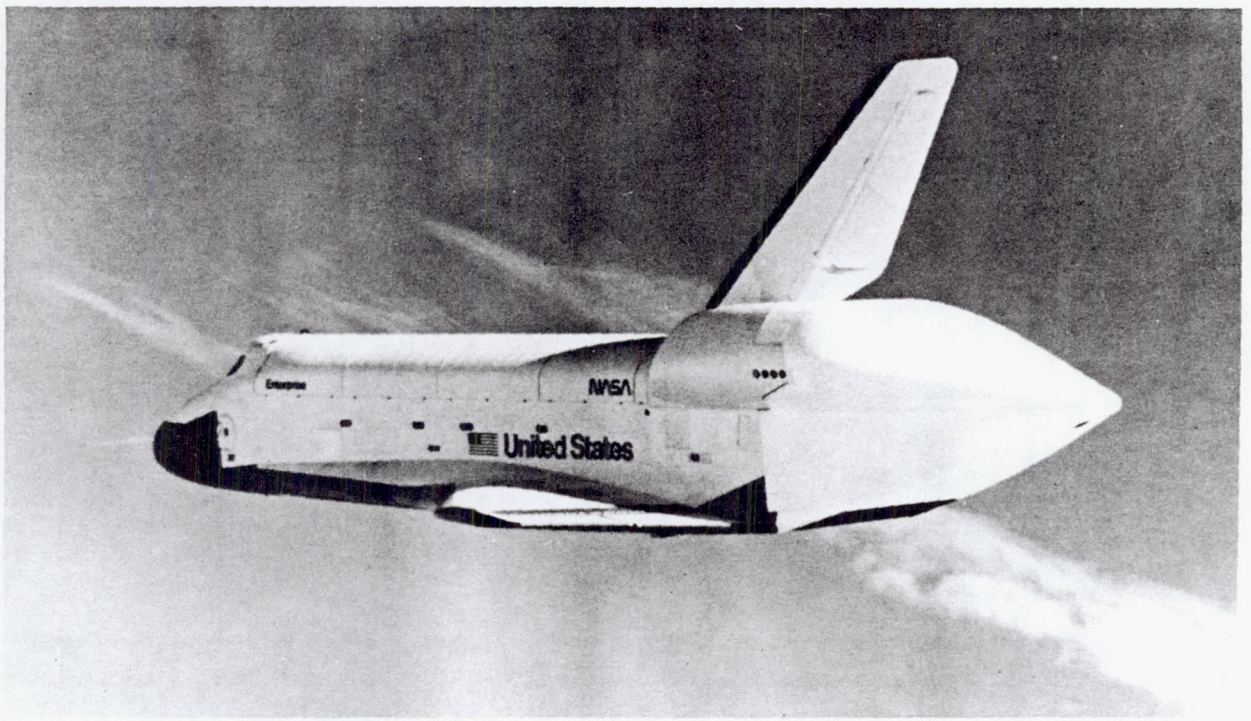
Major Participants – ITOS/NOAA and Delta launch vehicle program management, NASA Goddard Space Flight Center; spacecraft prime contractor, RCA; launch vehicle prime contractor, McDonnell Douglas.

Key Spacecraft Personnel		Affiliation
PM	A. Putera	NOAA-NESS
PS	I. L. Goldberg	NASA-GSFC
MG	M. L. Gardacz	NASA Headquarters
PM	G. A. Branchflower	NASA-GSFC
CO	W. C. Nyberg	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Very High Resolution Radiometer	PI	Ness Staff	NOAA-NESS
Vertical Temperature Prof. Radiometer	PI	Ness Staff	NOAA-NESS
	CO	W. E. Shenk	NASA-GSFC
Scanning Radiometer	PI	Ness Staff	NOAA-NESS
Solar Proton Monitor	PI	D. J. Williams	NOAA-ERL
	CO	W. E. Shenk	NASA-GSFC
	OI	H. H. Sauer	NOAA-ERL

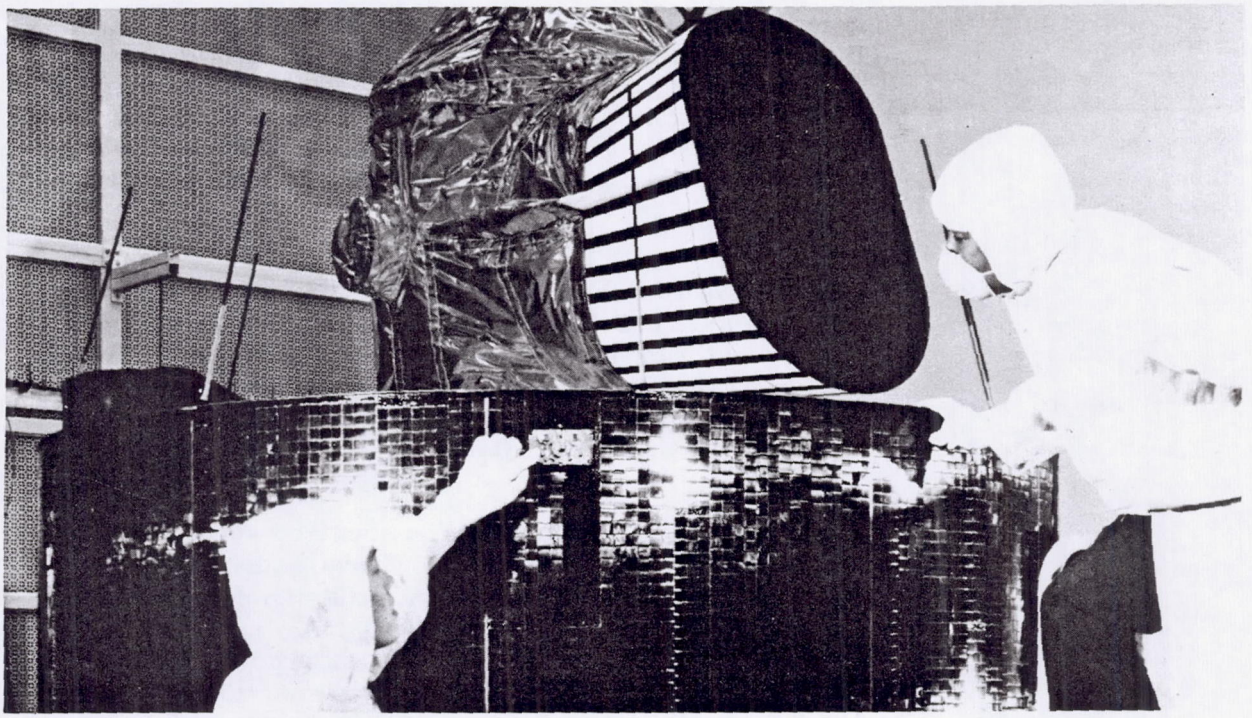


High over the Mojave Desert, the Space Shuttle Orbiter, "Enterprise," rides piggyback on its 747 carrier during approach and landing tests.

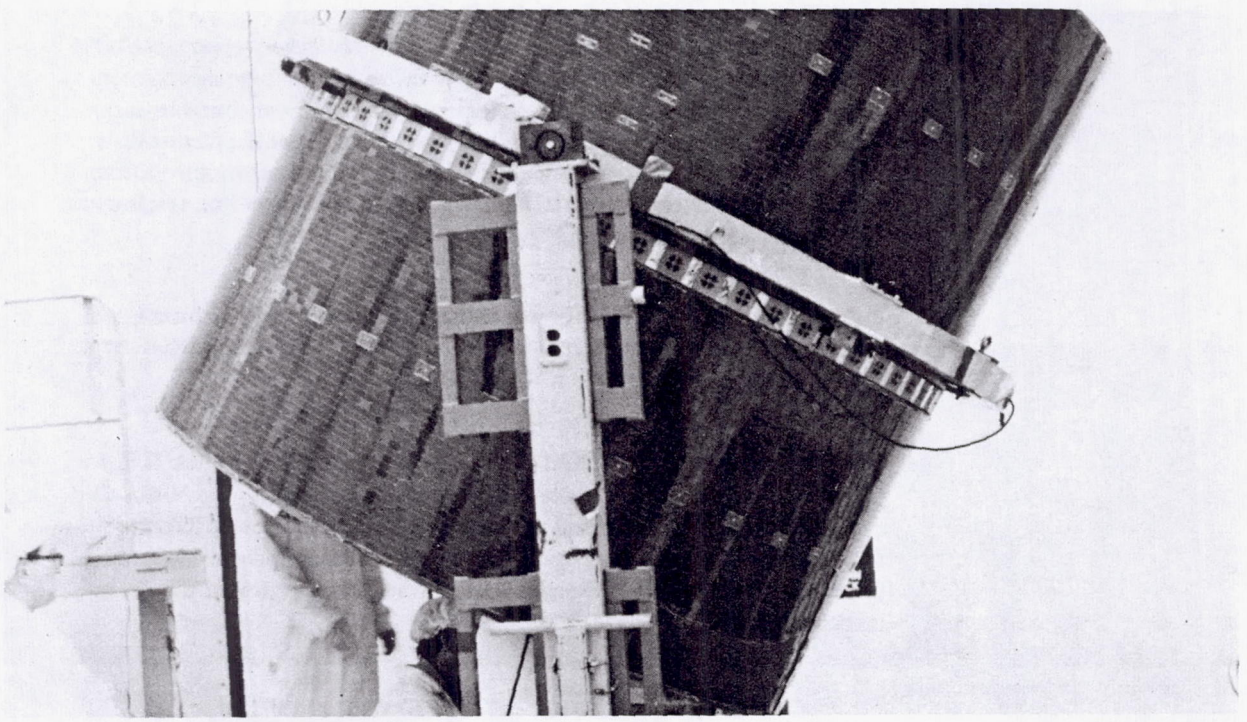


On August 12, 1977, the "Enterprise" earned its wings in the first free flight of the spacecraft. Astronauts Fred Haise and Gordon Fullerton piloted the maiden flight.

1977



Japan's first geostationary meteorological satellite undergoes testing prior to launch on July 14, 1977. The satellite was to help improve weather predictions over millions of square miles in the Western Pacific Ocean.



NATO-III B pre-launch testing. This satellite served the communications of the North Atlantic Treaty Organization. It was launched from Cape Canaveral Air Force Station on January 27, 1977.

NATO III B

Launch Vehicle – Delta 2914 - A three-stage Delta with an overall length of approximately 35 meters (116 feet) and a diameter of 2.4 meters (8 feet). The first stage was a modified Thor booster incorporating nine strap-on solid-fuel rocket motors powered by liquid oxygen and liquid hydrocarbon propellants. The second stage was powered by a liquid-fuel pressure-fed engine which was gimbal-mounted to provide pitch and yaw control through second-stage burn. The third stage was a spin-stabilized solid-propellant motor.

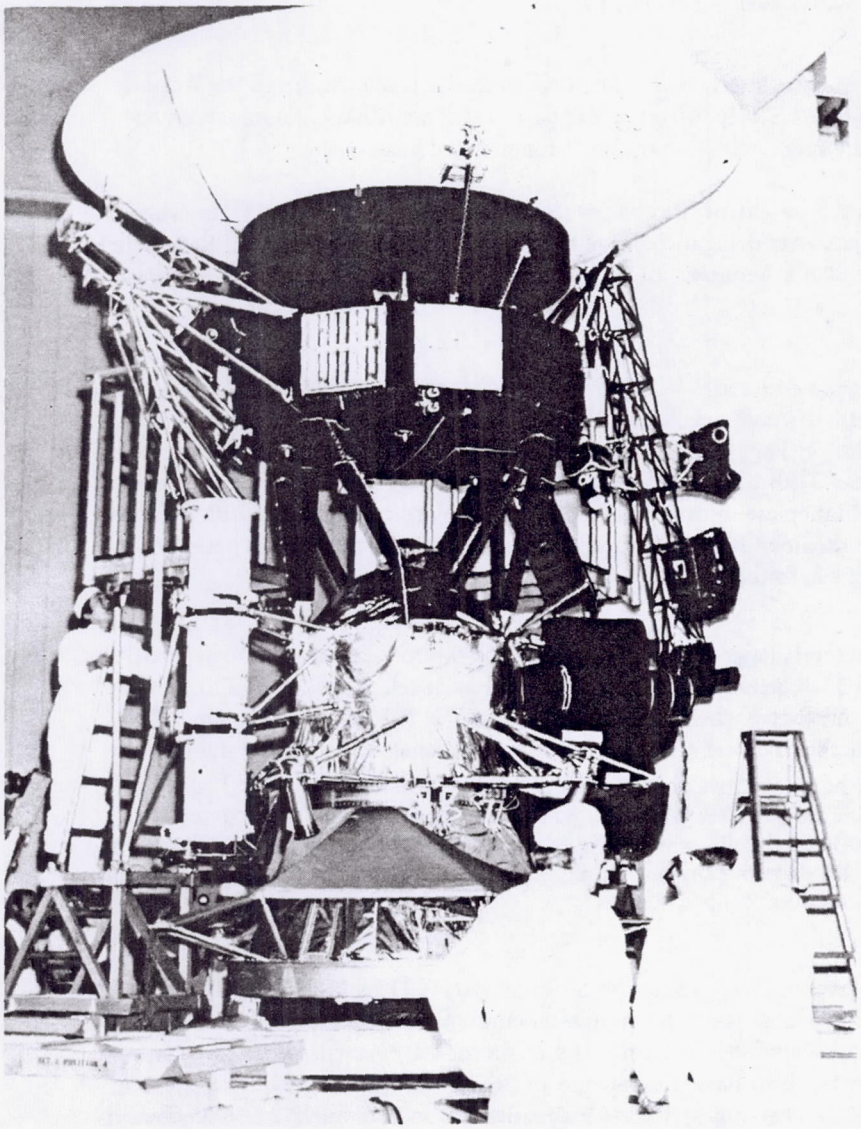
Spacecraft Description – Drum-shaped, the NATO IIIB was about 2.2 meters (86 inches) in diameter, 2.23 meters (88 inches) long, with an overall length of 3.1 meters (122 inches), including antennas. At launch it weighed 720 kg (1,528-lbs.) and after firing its onboard apogee kick motor to place it in stationary orbit, the weight reduced to 376 kg (830 lbs.). Design life of NATO IIIB is expected to be seven years.

Project Objectives – This third-generation spacecraft series was to provide communications services for North Atlantic Treaty Organization alliance countries – Belgium, Canada, Denmark, England, Germany, Iceland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Turkey and the United States. NATO IIIA, launched in April 1976, was in service over the Atlantic. NATO IIIB offered considerably more power than the two earlier NATO II satellites. It provided real-time communication for the nations of the NATO military alliance. The NATO Satcom System Control Center in Belgium near Supreme Headquarters, Allied Powers, Europe (SHAPE) scheduled and controlled all allied nations communications via NATO III.

Spacecraft Payload – Operating in the 7 to 8 GHz frequency range, NATO IIIB used three 20-watt traveling wave tubes with narrow-beam horn antennas permitting high capacity traffic transmission on three channels to and from relatively small ground stations. Unique "nod and tilt" antenna design kept the antennas pointed at the desired coverage zones on the ground. NATO III received translated frequency, and retransmitted voice, telegraph, facsimile, and wide-band digital data.

Project Results – NATO IIIB was launched January 27, 1977 from Cape Canaveral. It was initially placed in service over the Pacific, but was to be moved to the Atlantic to join NATO IIIA.

Major Participants – The NATO III program was managed by the U.S. Air Force Space and Missile Systems Organization for NATO. The NASA Goddard Space Flight Center and the Kennedy Space Center were responsible for integration and launch operations. Ford Aerospace produced the satellite and the McDonnell Douglas Astronautics Corp. provided the Delta launch vehicle.



During 1977 NASA sent two Voyager spacecraft to study Jupiter and Saturn planetary systems. Information gathered by the sensors, experiments, and cameras helped to shed light on the early history of the solar system.

PALAPA-B

Launch Vehicle – Delta 2914.

Spacecraft Description – Identical to the Canadian Anik and the Western Union WESTAR satellites, Palapa-B had a modified antenna to provide optimum illumination of the Indonesian landmass.

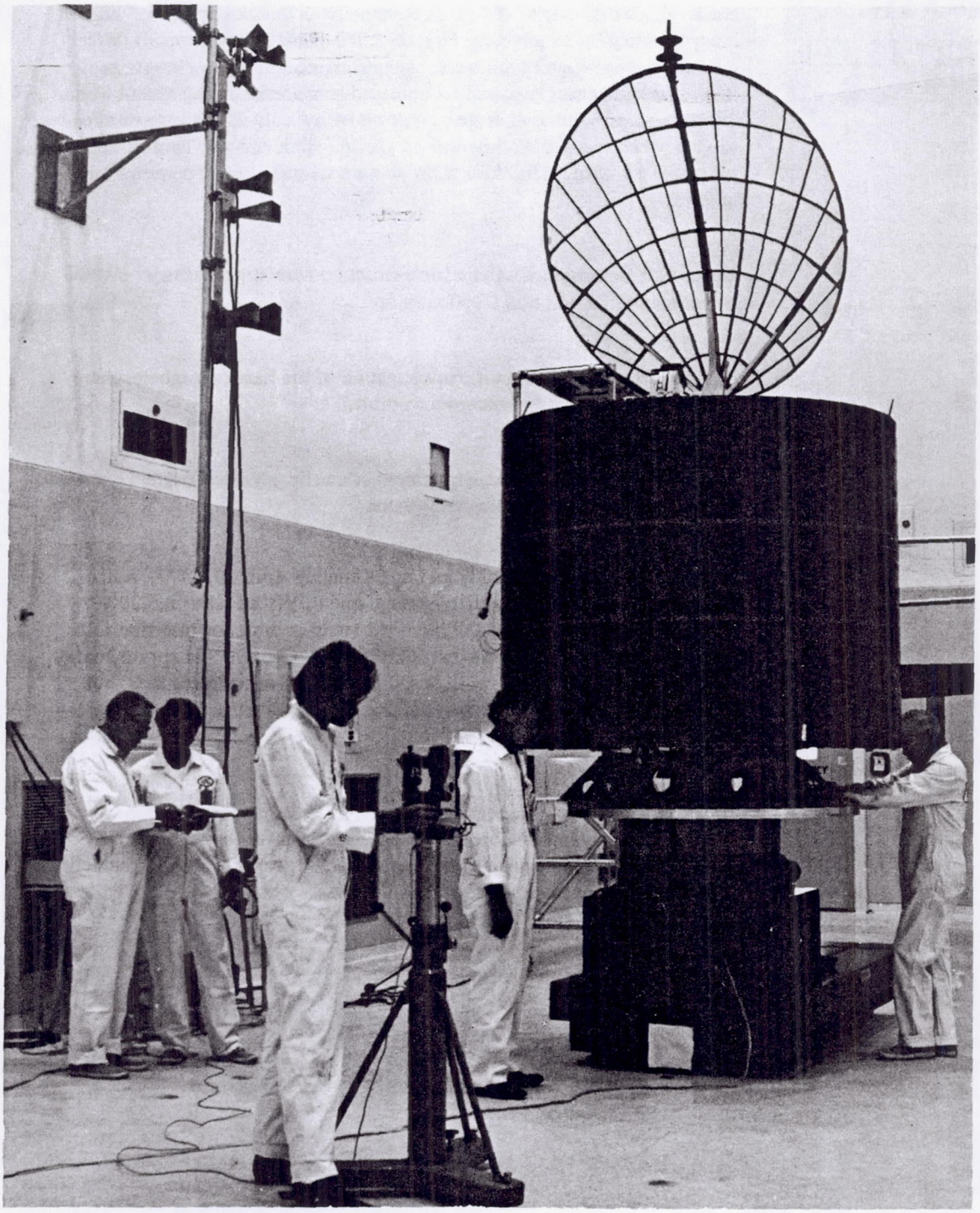
Launch weight of the spacecraft was 573 kg (1268 pounds). In-orbit weight after firing the apogee motor was 293 kg (645 pounds). Solar cells provided a minimum of 259 watts of power for the life of the Palapa-B satellite.

Program Objectives – Indonesian officials expected that the Palapa-A and -B satellites would enable the island nation to triple its telephone service by 1978. In 1977, the country had about 250,000 telephones, mostly in urban areas. With both Palapa satellites operational, the number of telephones could increase to over 650,000. In addition to telephone circuits, Palapa-B also provided telegraph, data, radio and television capabilities never before available to the nation.

Spacecraft Payload – Palapa-B provided 5,000 two-way telephone circuits or 12 television channels or combinations of telephone, TV, radio, telegraph, and data services. The drum-shaped body of Palapa-B was 156 cm (61.5 inches high) and 191 cm (75.1 inches) in diameter. Palapa's parabolic reflector antenna was 152 cm (60 inches) wide and extended 187 cm (73.5 inches) above the spacecraft. The satellite's solar drum was covered with 23,000 solar cells, which charged an on-board battery system to provide the spacecraft with power when the Earth intersects the Sun during the Spring and Autumn eclipse seasons.

Project Results – Launched on March 10, 1977 by NASA from Cape Canaveral, Florida, Palapa-B was in a synchronous orbit 35,800 kilometers (22,300 miles) above the Equator. The Delta rocket injected the satellite into a transfer orbit having an apogee of 36,323 km (22,570 miles), perigee of 230 km (150 miles), and an inclination at the Equator of 24.66 degrees. It was placed into operation on April 15, 1977 from its on-station position at 77° East longitude.

Major Participants – NASA Headquarters administered the Palapa program for the government of Indonesia. NASA project management for the Palapa spacecraft and the Delta launch vehicle were provided by the Goddard Space Flight Center with the Kennedy Space Center responsible for the launch. The satellite was designed and built by the Hughes Aircraft Company. Ford Aerospace and International Telephone and Telegraph built 15 Earth stations to complete the ground system controlled and operated by Perumtel, the Indonesian government-owned and operated telecommunications company.



Palapa-B, second Indonesian communications satellite, undergoes testing at Goddard Space Flight Center.

GEODYNAMICS EXPERIMENTAL OCEAN SATELLITE (GEOS/ESA)

Launch Vehicle – Delta 2914 – A three-stage Delta with an overall length of approximately 35 meters (116 feet) and a diameter of 2.4 meters (8 feet). The first stage was a modified Thor booster incorporating nine strap-on solid-fuel rocket motors powered by liquid oxygen and liquid hydrocarbon propellants. The second stage was powered by a liquid-fuel pressure-fed engine which was gimbal-mounted to provide pitch and yaw control through second-stage burn. The third stage was a spin-stabilized solid-propellant motor.

Spacecraft Description – Cylindrical structure with appendages for several experiments. Weight was 1,260 pounds.

Project Objectives – Scientific investigation of the Earth's magnetosphere from a vantage point in synchronous orbit.

Spacecraft Payload – Seven-experiment scientific payload designed to assess the characteristics of the magnetosphere.

Project Results – Launched from Cape Kennedy April 20, 1977. A malfunction during second stage/third stage spin-up placed Geos in 6,200- by 150-mile orbit rather than the intended transfer orbit for insertion into synchronous orbit. Launch controllers "lifted" Geos into an approximate 24,000- by 370-mile final orbit, and the satellite was returning data, but ESA officials stated that the original scientific mission has been "compromised."

Major Participants – Spacecraft management, ESA; spacecraft prime contractor, British Aircraft Corporation acting as lead for the STAR consortium; launch vehicle management and launch operations, NASA; launch vehicle prime contractor, McDonnell Douglas.

INTELSAT IVA Flight 4 and Flight 5

Launch Vehicle – Atlas Centaur. The Atlas Centaur, standing approximately 40.8 meters (134 feet) high, consisted of an Atlas SLV-3D booster and Centaur D-1A second stage. The Atlas booster developed 1,920 kilonewtons (431,300 lb.) of thrust at liftoff using two 822,920-newton (185,000) thrust booster engines, one 266,890-N (60,000 lb.) thrust sustainer engine and two vernier engines developed 2,890 N (650 lb.) thrust each. The two RL-10 engines on Centaur produced a total of 133,450 N (300,000 lb.) thrust. Both the Atlas and the Centaur were 3.048 m (10 ft.) in diameter.

Spacecraft Description – Drum-shaped, spin-stabilized main body 111 inches high and 94 inches in diameter. Antenna array brought total height to 267 inches. Solar arrays covering the sides of the main body provided approximately 600 watts of power. Solid propellant apogee motor mounted in the base of the cylinder provided 10,000 pounds of thrust. Antennas were mounted on a despun platform atop the cylinder. Weight at launch was about 3,300 pounds, in orbit, 1,750 pounds.

Project Objectives – Provide increased telecommunications capacity for Intelsat's global network. Intelsat IVA's were to serve as replenishments for earlier Intelsat IV satellites.

Spacecraft Payload – A 20-transponder system employing frequency reuse and new antennas provided at least 6,250 telephone circuits and two TV channels. Mechanically despun platform supported twin 53-inch dish transmit antennas. The receive antenna used two sets of feedhorns working in conjunction with a third dish reflector. Each transponder had a bandwidth of 36 MHz.

Project Results – Intelsat IVA F-4 was launched from Cape Canaveral on May 26, 1977 and placed in service at 340.5 degrees East longitude. Flight 5 was launched from Cape Canaveral on September 29, 1977, but suffered a booster failure.

Major Participants – Spacecraft manager, COMSAT Corp. for Intelsat; spacecraft prime contractor, Hughes Aircraft Co.; launch management, NASA Lewis Research Center; launch vehicle prime contractor, General Dynamics/Convair.

GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE (GOES/NOAA)

Launch Vehicle – Delta 2914.

Spacecraft Description – Cylindrical main body 106 inches high and 75 inches in diameter. Solar arrays provided 200 watts of power. The spin-stabilized spacecraft weighed about 1,375 pounds at launch, 650 pounds in orbit. Thirty-two-inch magnetometers extended from the end of the cylinder. An apogee kick motor attached to the spacecraft was ejected after synchronous orbit was achieved.

Project Objectives – Provide improved meteorological data on worldwide weather phenomena for improved forecasting and prediction. The satellite was to provide pictures of approximately one-quarter of the Earth at 30-minute intervals, day and night. Pictures and data aid scientists in weather detection and prediction, observations of ocean currents, monitoring river water levels, and other meteorological evaluations.

Spacecraft Payload – Visible/infrared spin-scan radiometer provided day and night global weather pictures.

Project Results – GOES 2 was placed in synchronous orbit after a June 16, 1977 launch from Cape Kennedy.

Major Participants – Spacecraft management, NASA Goddard Space Flight Center; spacecraft orbital operation, NOAA; spacecraft prime contractor, Ford Aerospace Corp.; launch vehicle management, NASA-Goddard; launch vehicle prime contractor, McDonnell Douglas; launch operations, NASA Unmanned Launch Operations, KSC.

Key Spacecraft Personnel		Affiliation
PM	R. H. Pickard	NASA-GSFC
PS	W. E. Shenk	NASA-GSFC
MG	A. J. Cervenka	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Spin-Scan Radiometer-VISSR	PI	Ness Staff	NOAA-NESS
	OI	W. E. Shenk	NASA-GSFC
Solar Energetic Particles	PI	D. J. Williams	NOAA-ERL
Solar X-Ray Monitor	PI	D. J. Williams	NOAA-ERL
	OI	R. F. Donnelly	NOAA-ERL
Biaxial Fluxgate Magnetometer	PI	D. J. Williams	NOAA-ERL
	OI	J. N. Barfield	NOAA-ERL
	OI	H. H. Sauer	NOAA-ERL
Meteorological Data Collection System	PI	NESS Staff	NOAA-NESS

GEOSTATIONARY METEOROLOGICAL SATELLITE (GMS) Himawari

Launch Vehicle – Delta 2914.

Spacecraft Description – The cylindrical body of the GMS satellite weighed 1,476 pounds (670 kg) at launch. A special sun shield mounted atop the drum-shaped satellite was used to protect the scanning instrument that took high-resolution weather photos every 30 minutes, day and night.

Project Objectives – Japan's GMS, one of five weather satellites to monitor weather conditions over a vast Pacific area that includes Japan, Korea, Taiwan, the Philippines, Australia, New Zealand, Indonesia, Malaysia, Vietnam, Thailand, Burma, Laos, Tibet, China and Mongolia. GMS joined two U.S. Geostationary Operational Environmental Satellites (GOES) in weather watching. It was renamed Himawari after launch.

Spacecraft Payload – The main scientific instrument onboard the GMS was a device called VISSR, meaning Visible and Infrared Spin-Scan Radiometer. It produced high-resolution visible-light pictures by day and infrared images day and night every 30 minutes, 24 hours a day, to provide early storm detection. Also aboard the GMS was a Space Environmental Monitor that measured high velocity particles of ionized gases that spew from the Sun.

Project Results – GMS was successfully launched on July 14, 1977 from Cape Canaveral, Florida aboard a Delta 2914 rocket. It achieved a 22,300-mile-high (35,800 km) synchronous orbit over the Equator at 140 degrees East longitude, directly south of Japan.

Major Participants – GMS was designed and developed by Hughes Aircraft Co. of California for Nippon Electric Company, prime contractor to Japan's National Space Development Agency. Launch operations were conducted by NASA's Kennedy Space Center. The Delta launch vehicle's prime contractor was the McDonnell Douglas Astronautics Company.

Key Spacecraft Personnel		Affiliation
PS	JMA Staff	Japanese Meteorological Agency
PM	N. Kodaira	Meteorological Satellite Center

Experiment	Experiment Personnel		Affiliation
Visible + Iridium Radiometer-VISSR	PI	JMA Staff	Japanese Meteorological Agency
Space Environment Monitor	PI	T. Kohno	Meteorological Research Institute
Weather Communications	PI	JMA Staff	Japanese Meteorological Agency

HIGH ENERGY ASTRONOMY OBSERVATORY-A (HEAO - A)

Launch Vehicle – Atlas Centaur. The Atlas Centaur, standing approximately 40.8 meters (134 feet) high, consisted of an Atlas SLV-3D booster and Centaur D-1A second stage. The Atlas booster developed 1,920 kilonewtons (431,300 lb.) of thrust at liftoff using two 822,920-newton (185,000) thrust booster engines, one 266,890-N (60,000 lb.) thrust sustainer engine and two vernier engines developed 2,890 N (650 lb.) thrust each. The two RL-10 engines on Centaur produced a total of 133,450 N (30,000 lb.) thrust. Both the Atlas and the Centaur were 3,048 M (10 ft.) in diameter.

Spacecraft Description – A 10.5-foot high hexagonal experiment module atop HEAO's octagonal spacecraft equipment module. A rectangular solar array deployed from the top side of the experiment module, bringing total spacecraft height to 20 feet. Two other arrays affixed along one side of the experiment module combined with the topside array to deliver 460 watts of electrical power to HEAO's experiments and spacecraft subsystems. HEAO 1 was one of the heaviest satellites ever flown, weighing in at nearly 7,000 pounds. (Of that, more than 2,600 pounds was scientific payload weight.) Its attitude control system used star trackers, rate gyros and reaction jets to achieve a "normal" state of two revolutions per hour, turning end-over-end. Additionally, HEAO 1's "spin" could be arrested for several hours, enabling its use as a stationary pointing platform to study items of special interest. HEAO's communications system was dual-frequency S-band with onboard tape recorders allowing 220 minutes of data storage.

Spacecraft Payload – Four science instruments: large area X-ray survey experiment, to make an all-sky map of discrete sources in the 0.15 to 20 keV range; cosmic X-ray experiment, to provide an all-sky map of diffuse sources in the range from 0.2 to 60 keV; scanning modulator collimator experiment, to measure angular structure, location and size of X-rays in the range from 1 to 15 keV, with ability to determine celestial positions of selected sources to about 5 arc-seconds; and the hard X-ray and low gamma ray instrument, to detect and measure X-rays and gamma rays in the range from 10 keV to 10 MeV.

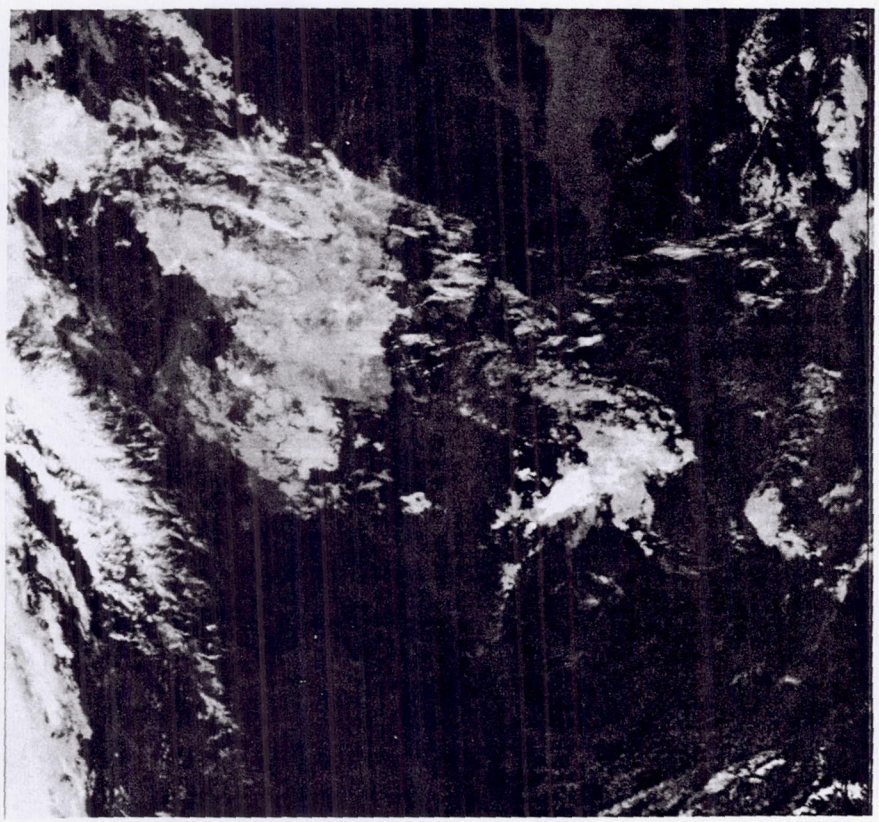
Project Objectives – Survey and map X-ray sources throughout the celestial sphere; measure low energy gamma-ray flux; investigate astronomical phenomena such as black holes, quasars, and pulsars; provide an all-sky survey of "soft" X-rays (0.1 keV) through high-energy (10 MeV) gamma rays, with accurate location of their sources.

Project Results – HEAO 1 was launched August 12, 1977 from Cape Canaveral and placed in a circular near-Earth orbit of about 240 miles with an inclination of about 22 degrees.

Major Participants – Overall management, NASA Office of Space Science; program management, NASA Marshall Space Flight Center; spacecraft prime contractor, TRW; launch vehicle management, NASA Lewis Research Center; launch vehicle prime contractor, General Dynamics.

Key Spacecraft Personnel		Affiliation
PM	F. A. Speer	NASA-MSFC
PS	F. B. McDonald	NASA-GSFC
MG	R. E. Halpern	NASA Headquarters
SC	A. G. Opp	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Large Area X-Ray Survey	PI	H. D. Friedman	U.S. Naval Research Laboratory
Cosmic X-Ray Experiment	PI	E. A. Boldt	NASA-GSFC
	OP	G. P. Garmire	California Institute of Technology
Scanning Modulation Collector	OP	H. V. C. Bradt	Massachusetts Institute of Technology
	PI	D. Schwartz	Smithsonian Astrophysical Laboratory
MeV Range Gamma Ray Telescope	PI	L. E. Peterson	University of California, San Diego
	OP	W. H. E. Lewin	Massachusetts Institute of Technology



ITOS H/NOAA-5 took this high resolution photograph on May 1, 1977. It includes "heat signatures," dark areas of New York City, Buffalo, Philadelphia, Baltimore, Washington, D.C., and Richmond, Va. Colder water from Labrador current and the Great Lakes shows up as light areas.

1977

VOYAGER 1 AND 2

Launch Vehicle – Titan III-Centaur. Two 120-inch solid propellant boosters (stage zero) on opposite sides of liquid-propellant "core vehicle." Stage zero generated 2.4 million pounds of thrust at liftoff; first stage, 470,000 pounds. Stage zero was 85 feet tall; overall vehicle, 125 feet.

Spacecraft Description – Voyager's "flying dish" appearance was dominated by its 12-foot (3.66-meter) diameter high gain antenna. Other major elements of the spacecraft included the mission module, a ten-sided box which carried spacecraft housekeeping systems and some instrument payload, and the propulsion module, which was jettisoned after it provided the final push to inject Voyager into its Jupiter transfer trajectory. Appendages to the main body of the spacecraft included a number of booms for experiments as well as the boom which held the three radioisotope thermoelectric generators (RTG's) which provided electrical power to the spacecraft. Usable electrical power produced by the RTG system ranged from about 420 watts at the beginning of the mission to about 380 watts after Saturn encounter. The three-axis stabilized spacecraft employed a hydrazine system and a highly automated computer command on-board control system. Weight of each Voyager at launch was about 4,600 pounds (2,100 kg); after injection into Jupiter trajectory and jettison of the propulsion module, each spacecraft weighed about 1,800 (825 kg), of which about 230 pounds (105 kg) was science payload.

Project Objectives – Scientific investigation of Jupiter and Saturn to expand on the knowledge provided by the precursor Pioneer 10 and 11 missions, with an option to conduct the first spaceborne investigation of Uranus.

Spacecraft Payload – Communications payload provided for transmission at both S-band and X-band, with downlink data rates in X-band as high as 115 kbps (at Jupiter) to enable real time video transmission. (At the 115 kbps rate, full frame readout was accomplished in 48 seconds.) Onboard data storage capacity was about 536 million bits. The system sent data to ground stations of NASA's deep space network with their 210-foot antennas. Each spacecraft carried ten science instruments and used the spacecraft radio for an eleventh science experiment, called the Radio Science Experiment, to obtain occultation and celestial mechanics data. The ten science experiment packages were: imaging (two TV cameras one with narrow-angle 1,500 mm f/8.5 optics, the other a wide-angle with 200 mm f/3 optics); infrared spectroscopy and radiometry; ultraviolet spectroscopy; photopolarimetry; plasma detection; low-energy charged particle detection; cosmic ray detection; magnetometry; planetary radio astronomy; and plasma wave detection.

Project Results - Voyager 2 was launched August 20, 1977, from Cape Canaveral. It was scheduled to make its closest approach to Jupiter in July 1979. Voyager 1 was launched September 5, 1977; it began substantive measurements of the Jovian system on January 6, 1979, encountered Jupiter at a closest approach distance of 348,890 km at 12:04.6 UTC (Universal Time, coordinated) March 1979, and completed its detailed observations of Jupiter on April 13, 1979. During this 98-day period, nearly continuous measurements of the Jovian system and the nearby interplanetary medium were accomplished, providing data for testing current Jovian theories and models and for making new, unexpected discoveries.

The second Voyager spacecraft began its close Saturn observations in early June 1981 and made its closest approach to the planet's northern hemisphere on August 25, 1981. Then, due to its launch during a period of rare planetary alignment occurring only once every 175 years. Voyager 2 continued on to a rendezvous with the seventh planet, Uranus, in January 1986, and perhaps even the eighth planet, Neptune, in August 1989.

Major Participants - Overall program direction: NASA Office of Space Science; spacecraft construction, tracking and mission control, JPL; launch vehicle management, NASA-Lewis Research Center; launch vehicle contractors, Martin (Titan) and General Dynamics (Centaur), USAF Space and Missile Systems Organization.

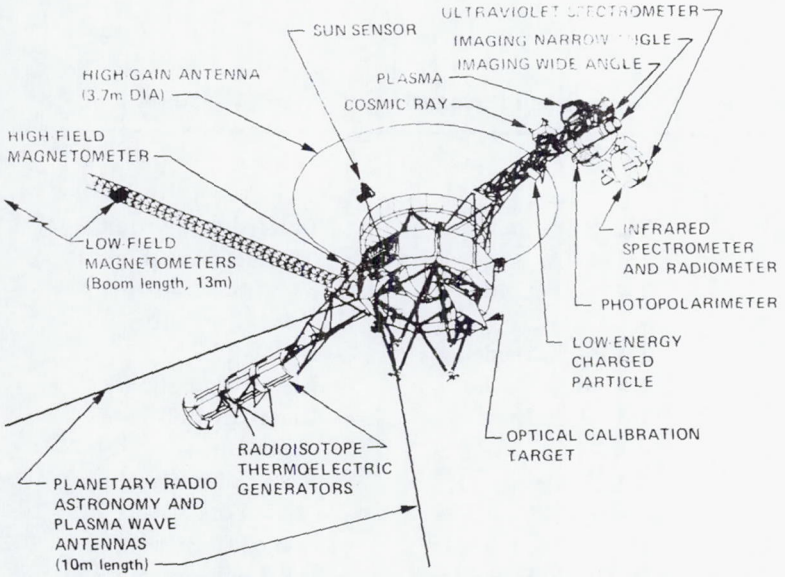
Voyager Management Team: NASA Office of Space Science--Noel W. Hinners, Associate Administrator for Space Science; Anthony J. Calio, Deputy Associate Administrator; S. Ichtiaque Rasool, Deputy Associate Administrator--Science; A. Thomas Young, Director, Lunar and Planetary Programs; Arthur Reetz, Jr., Deputy Program Manager; and Earl W. Glahn, Flight Support Manager. NASA Office of Tracking and Data Acquisition--Gerald M. Truszynski, Associate Administrator for Tracking and Data Acquisition; Charles A. Taylor, Director, Network Operations and Communication Programs; Arnold C. Belcher, Program Manager for DSN Operations; Frederick B. Bryant, Director, Network System Development Programs; and Maurice E. Binkley, Director DSN Systems. NASA Office of Space Flight--John F. Yardley, Associate Administrator for Space Flight; Joseph B. Mahon, Director, Expendable Launch Vehicles; Joseph E. McGolrick, Director, Small and Medium Launch Vehicles; and B. C. Lam, Titan III Manager. Jet Propulsion Laboratory, Pasadena, California--Bruce C. Murray, Laboratory Director; General Charles H. Terhune, Jr., Deputy Laboratory Director; Robert J. Parks, Assistant Laboratory Director for Flight Projects; John R. Casani, Project Manager; Charles E. Kohlhase, Jr., Mission Analysis and Engineering Manager; James E. Long, Science Manager; Richard P. Laeser, Mission Operations System Manager; Esker K. Davis, Tracking and Data System Manager; James F. Scott, Mission Computing

Voyager Management Team continued:

System Manager; Michael J. Sander, Mission Control and Computing Center Manager; Ronald F. Draper, Spacecraft System Engineer; William S. Shipley, Spacecraft Development Manager; William G. Fawcett, Science Instruments Manager; and Michael Devirian, Chief of Mission Operations. Lewis Research Center, Cleveland, Ohio--Bruce T. Lundin, Center Director; Andrew J. Stofan, Director, Launch Vehicles; Carl B. Wentworth, Chief, Program Integration Division; Gary D. Sagerman, Voyager Mission Project Engineer; Richard P. Geye, Voyager Mission Project Engineer; Richard A. Flage, LV Test Integration Engineer; Richard E. Orzechowski, TDS Support Engineer; Larry J. Ross, Chief, Vehicles Engineering Division; James E. Patterson, Associate Chief, Engineering Division; and Frank L. Manning, TC-6 and TC-7 Vehicle Engineer. Kennedy Space Center, Florida--Lee R. Scherer, Center Director; Walter J. Kapryan, Director of Space Vehicle Operations; George F. Page, Director, Expendable Vehicles; John D. Gossett, Chief, Centaur Operations Division; Creighton A. Terhune, Chief Engineer, Operations Division; Jack E. Baltar, Centaur Operations Branch; Donald C. Sheppard, Chief, Spacecraft and Support Operations Division; and James E. Weir, Spacecraft Operations Branch.

Key Spacecraft Personnel		Affiliation
Voyager 2--		
MG	R. A. Mills	NASA Headquarters
SC	M. A. Mitz	NASA Headquarters
PM	R. L. Heacock	NASA-JPL
PS	E. C. Stone	California Institute of Technology
Voyager 1, Mariner 77A--		
SC	M. A. Mitz	NASA Headquarters
PS	E. C. Stone	California Institute of Technology
PM	R. L. Heacock	NASA-JPL
MG	R. A. Mills	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Voyager 2			
Imaging	TL	B. A. Smith	University of Arizona
	TM	G. A. Briggs	NASA Headquarters
	TM	A. F. Cook	Smithsonian Astrophysical Observatory
	TM	G. E. Danielson	NASA-JPL
	TM	M. E. Davies	Rand Corporation
	TM	G. E. Hunt	University College London
	TM	T. Owen	State University of New York
	TM	C. Sagan	Cornell University
	DT	L. A. Soderblom	U.S. Geological Survey
	TM	V. E. Suomi	University of Wisconsin
	TM	T. V. Johnson	NASA-JPL
	TM	H. Masursky	U.S. Geological Survey
Coherent S + X Band Radiometer	TM	G. F. Lindal	NASA-JPL
	TM	G. S. Levy	NASA-JPL
	TM	T. A. Croft	SRI International
	DT	G. L. Tyler	Stanford University
	TL	V. R. Eshleman	Stanford University
	TM	J. D. Anderson	NASA-JPL
	TM	G. F. Wood	NASA-JPL
Iridium Interferometer	CI	C. A. Ponnamperuma	University of Maryland
	CI	P. J. Gierasch	Cornell University
	CI	J. A. Pirraglia	NASA-GSFC
	CI	R. E. Samuelson	NASA-GSFC
	CI	W. C. Maguire	NASA-GSFC
	CI	J. C. Pearl	NASA-GSFC
	CI	V. G. Kunde	NASA-GSFC
	CI	P. D. Lowman, Jr.	NASA-GSFC
	PI	R. A. Hanel	NASA-GSFC
	CI	B. J. Conrain	NASA-GSFC
	CI	D. Gautter	Paris Observatory
Ultraviolet Spectroscopy	CI	A. Dalgarno	Smithsonian Astrophysical Observatory
	CI	J. C. McConnell	York University
	CI	R. M. Goody	Harvard University
	CI	T. M. Donahue	University of Michigan
	CI	M. B. McElroy	Harvard University
	CI	M. J. S. Belton	Kitt Peak National Observatory
	CI	D. F. Strobel	U.S. Naval Research Laboratory



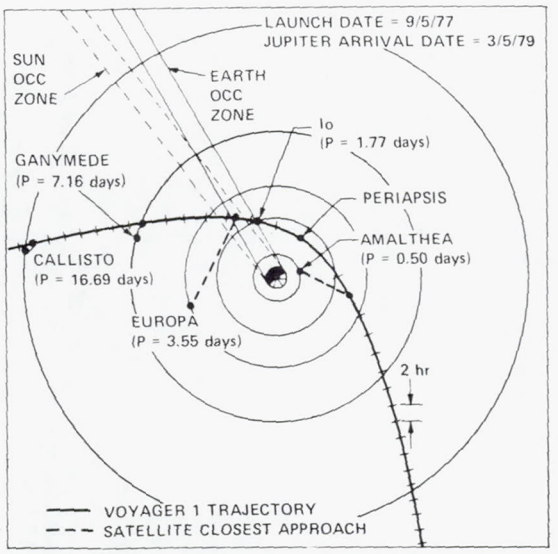
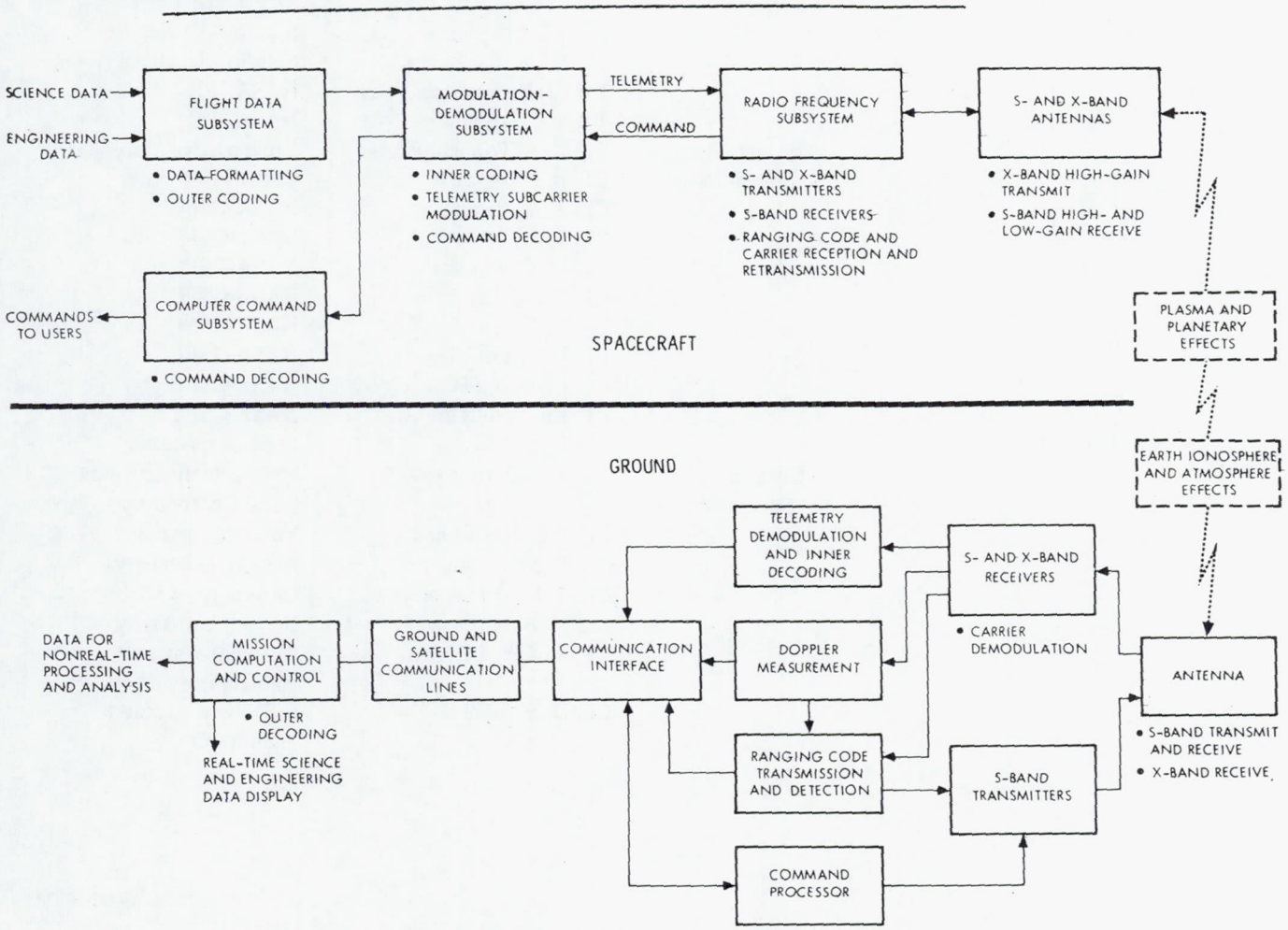


Fig. 1 (left). Voyager spacecraft. An advanced three-axis attitude stabilized spacecraft for exploration of the outer planets. The location of the science instruments on the spacecraft is noted. The optical calibration target is a specially coated plate used to provide flat-field illumination for ISS and PPS and a warm thermal body of known temperature for the IRIS. The scan platform, which contains these instruments, can be pointed to the plate. The spacecraft is usually oriented with the high-gain antenna directed toward Earth. The total spacecraft mass is approximately 825 kg. Fig. 2 (right). Voyager 1 Jupiter encounter geometry. This view from the planet north pole shows the trajectory closest approach geometry to the planet and selected satellites, satellite periods, 2-hour tick marks along the trajectory path, and the Earth and sun occultation zones through which the spacecraft flies.



Block diagram of the Voyager telecommunications system.

Experiment		Experiment Personnel	Affiliation
	PI	A. L. Broadfoot	Kitt Peak National Observatory
	CI	H. W. Moos	Johns Hopkins University
	CI	J. E. Blamont	CNRS-SA
	CI	J. L. Bertaux	CNRS-SA
Fluxgate Magnetometer	CI	R. P. Lepping	NASA-GSFC
	CI	F. M. Neubauer	Braunschweig Tech University
	CI	K. W. Behannon	NASA-GSFC
	CI	L. F. Burlaga	NASA-GSFC
	PI	N. F. Ness	NASA-GSFC
	CI	M. H. Aquna	NASA-GSFC
Faraday Cup Detector	CI	A. J. Lazarus	Massachusetts Institute of Technology
	CI	S. Olbert	Massachusetts Institute of Technology
	PI	H. S. Bridge	Massachusetts Institute of Technology
	CI	J. W. Belcher	Massachusetts Institute of Technology
	CI	V. M. Vasyliunas	MPI-Aeronomy
	CI	L. F. Burlaga	NASA-GSFC
	CI	J. H. Binsack	Massachusetts Institute of Technology
	CI	G. L. Siscoe	University of California, Los Angeles
	CI	A. J. Hundhausen	National Center for Atmospheric Research
	CI	R. E. Hartle	NASA-GSFC
	CI	K. W. Ogilvie	NASA-GSFC
	CI	J. D. Sullivan	Massachusetts Institute of Technology
	CI	C. M. Yeates	NASA-JPL
Particles Analyzer/Telescope	CI	C. O. Bostrom	Applied Physics Laboratory
	CI	T. P. Armstrong	University of Kansas
	CI	W. I. Axford	MPI-Aeronomy
	CI	G. Gloeckler	University of Maryland
	CI	L. J. Lanzerotti	Bell Telephone Laboratory
	PI	S. M. Krimigis	Applied Physics Laboratory
	CI	C. Y. Fan	University of Arizona

Experiment	Experiment Personnel		Affiliation
Cosmic Ray Telescope	PI	R. E. Vogt	California Institute of Technology
	CI	J. R. Jokipii	University of Arizona
	CI	E. C. Stone	California Institute of Technology
	CI	F. B. McDonald	NASA-GSFC
	CI	J. H. Trainor	NASA-GSFC
	CI	W. R. Webber	University of New Hampshire
SF. RF RCVR (0.02-40 MHz)	CI	W. E. Brown, Jr.	NASA-JPL
	CI	S. Gulkis	NASA-JPL
	CI	C. C. Harvey	Paris Observatory
	CI	Y. Leblanc	Paris Observatory
	CI	D. H. Staelin	Massachusetts Institute of Technology
	CI	A. Boischot	Paris Observatory
	CI	T. D. Carr	University of Florida
	CI	F. T. Haddock	University of Michigan
	PI	J. W. Warwick	Science Applications, Incorporated
	CI	J. K. Alexander, Jr.	NASA-GSFC
	CI	R. Phillips	NASA-JPL
	CI	R. G. Pelizer	University of Colorado
	CI	J. B. Pearce	Science Applications, Incorporated
	CI	A. C. Riddle	Science Applications, Incorporated
Photo-polarimeter	PI	C. F. Lillie	University of Colorado
	CI	C. W. Hord	University of Colorado
	CI	K. Pang	Science Applications, Incorporated
	CI	J. E. Hansen	NASA-GISS
	CI	D. L. Coffeen	NASA-GISS
Plasma Wave (0.01-56 kHz)	PI	F. L. Scarf	TRW Systems Group
	CI	D. A. Gurnett	University of Iowa
Voyager 1			
Imaging	TL	B. A. Smith	University of Arizona
	TM	G. A. Briggs	NASA Headquarters
	TM	A. F. Cook	SAO
	TM	G. E. Danielson	NASA-JPL
	TM	M. E. Davies	Rand Corporation
	TM	G. E. Hunt	University College London
	TM	T. Owen	State University of New York
	TM	C. Sagan	Cornell University

Experiment	Experiment Personnel		Affiliation
	DT	L. A. Soderblom	U.S. Geological Survey
	TM	V. E. Suomi	University of Wisconsin
	TM	T. V. Johnson	NASA-JPL
	TM	H. Masursky	U.S. Geological Survey
Coherent S + X Band Radio	TL	V. R. Eshleman	Stanford University
	TM	J. D. Anderson	NASA-JPL
	TM	T. A. Croft	SRI International
	DT	G. L. Tyler	Stanford University
	TM	G. F. Lindal	NASA-JPL
	TM	G. S. Levy	NASA-JPL
	TM	G. E. Wood	NASA-JPL
Iridium Interferometer	PI	R. A. Hanel	NASA-GSFC
	CI	B. J. Conrath	NASA-GSFC
	CI	V. G. Konde	NASA-GSFC
	CI	P. D. Lowman, Jr.	NASA-GSFC
	CI	W. C. Maguire	NASA-GSFC
	CI	J. C. Pearl	NASA-GSFC
	CI	J. A. Pirraglia	NASA-GSFC
	CI	R. E. Samuelson	NASA-GSFC
	CI	P. J. Gierasch	Cornell University
	CI	C. A. Ponnamperuma	University of Maryland
	CI	D. Gautier	Paris Observatory
Ultraviolet Spectrometer	CI	H. W. Moos	Johns Hopkins University
	CI	M. J. S. Belton	Kitt Peak National Observatory
	CI	D. F. Strobel	U.S. Naval Research Laboratory
	PI	A. L. Broadfoot	Kitt Peak National Observatory
	CI	T. M. Donahue	University of Michigan
	CI	M. B. McElroy	Harvard University
	CI	J. C. McConnell	York University
	CI	R. M. Goody	Harvard University
	CI	A. Dalgarno	Smithsonian Astrophysical Observatory
	CI	J. E. Blamont	CNRS-SA
	CI	J. L. Bertaux	CNRS-SA
	CI	S. K. Aireya	University of Michigan
	CI	B. R. Sandel	University of Southern California
	CI	D. F. Shemansky	University of Southern California
Fluxgate Magnetometers	PI	N. F. Ness	NASA-GSFC
	CI	M. H. Acuna	NASA-GSFC
	CI	K. W. Behannon	NASA-GSFC
	CI	L. F. Burlaga	NASA-GSFC
	CI	R. P. Lepping	NASA-GSFC
	CI	F. M. Neubauer	Braunschweig Tech University

Experiment	Experiment Personnel		Affiliation
Faraday Cup Detectors	PI	H. S. Bridge	Massachusetts Institute of Technology
	CI	J. W. Belcher	Massachusetts Institute of Technology
	CI	J. H. Binsack	Massachusetts Institute of Technology
	CI	A. J. Lazarus	Massachusetts Institute of Technology
	CI	S. Olbert	Massachusetts Institute of Technology
	CI	V. M. Vasyliunas	MPI-Aeronomy
	CI	L. F. Borlaga	NASA-GSFC
	CI	B. E. Hartle	NASA-GSFC
	CI	K. W. Ogilvie	NASA-GSFC
	CI	G. L. Siscoe	University of California, Los Angeles
	CI	A. J. Hundhausen	National Center for Atmospheric Research
	CI	J. D. Sullivan	Massachusetts Institute of Technology
	CI	C. M. Yeates	NASA-JPL
Particle Analyzer/ Telescope	CI	C. Y. Fan	University of Arizona
	CI	G. Gloeckler	University of Maryland
	CI	L. J. Lanzerotti	Bell Telephone Laboratory
	PI	S. M. Krimigis	Applied Physics Laboratory
	CI	T. P. Armstrong	University of Kansas
	CI	W. I. Axford	MPI-Aeronomy
	CI	C. O. Bostrom	Applied Physics Laboratory
Cosmic Ray Telescope	PI	R. E. Vogt	California Institute of Technology

Experiment	Experiment Personnel		Affiliation
	CI	J. R. Jokipii	University of Arizona
	CI	E. C. Stone	California Institute of Technology
	CI	F. B. McDonald	NASA-GSFC
	CI	J. H. Trainor	NASA-GSFC
	CI	W. R. Webber	University of New Hampshire
SF RF Receiver (0.02-40 MHz)	PI	J. W. Warwick	Science Applications, Incorporated
	CI	J. K. Alexander, Jr.	NASA-GSFC
	CI	T. D. Carr	University of Florida
	CI	F. T. Haddock	University of Michigan
	CI	D. H. Staelin	Massachusetts Institute of Technology
	CI	A. Boischot	Paris Observatory
	CI	C. C. Harvey	Paris Observatory
	CI	Y. Leblanc	Paris Observatory
	CI	W. E. Brown, Jr.	NASA-JPL
	CI	S. Gulkis	NASA-JPL
	CI	R. Phillips	NASA-JPL
	CI	J. B. Pearce	Science Applications, Incorporated
	CI	A. C. Riddle	Science Applications, Incorporated
	CI	R. G. Peltzer	University of Colorado
Radio Receiver	PI	C. F. Lillie	University of Colorado
	CI	C. W. Hord	University of Colorado
	CI	K. Pang	Science Applications, Incorporated
	CI	J. E. Hansen	NASA-GISS
	CI	D. L. Coffeen	NASA-GISS
Plasma Wave (0.01-56 kHz)	PI	F. L. Scarf	TRW Systems Group
	CI	D. A. Gurnett	University of Iowa

SIRIO/Italy

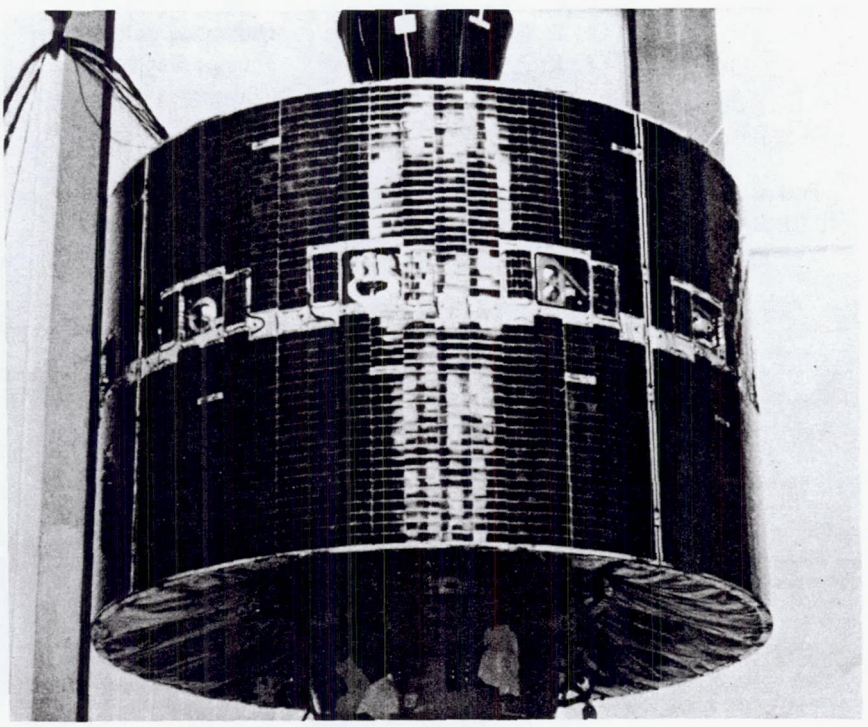
Launch Vehicle – Delta 2313.

Spacecraft Description – Spacecraft was 4.6 feet in diameter, 6.5 feet in height, including apogee boost motor. It weighed 880 lbs. SIRIO is Italian for SIRIUS the dog star, also an acronym for industrial research oriented Italian satellite: Satellite Italiano Riceroa Industriale Orientata.

Project Objectives – Principal experiment was designed for study of propagation characteristics of radio waves transmitted at super high frequencies during adverse weather conditions, including rain, snow and fog. In addition, Italian experimenters wanted to acquire expertise in advanced space technology while developing a low cost "bus" for future communications tests.

Project Results – Launched from Eastern Test Range, Kennedy Space Center, August 25, 1977, into a geosynchronous orbit over the equator just south of the west coast of Africa.

Major Participants – Italy's Consiglio Nazionale della Ricerche (CNR) in cooperation with Centro Studi Telecommunicazioni Spaziali del Politecnico (CSTS), Milan, with direct responsibility for spacecraft development under Compagnia Industriale Aerospaziale, Rome. Goddard Space Flight Center was responsible for the Delta launch vehicle, McDonnell-Douglas Astronautics Co., prime contractor. Kennedy Space Center responsible for launch operations.



Italy's SIRIO satellite undergoes testing. It was launched from Kennedy Space Center in Florida on August 25, 1977.

INTERNATIONAL SUN EARTH EXPLORER-A/B

Launch Vehicle – Delta 291.

Spacecraft Description – The International Sun Earth Explorer (ISEE-A) was a 16-sided polyhedron measuring approximately 1.73 meters across and 1.61 meters high. Its main body consisted of an 84-centimeter conical center tube. The lower end of the center tube mated with the launch vehicle and the upper end with the ISEE-B.

ISEE-B was a cylinder with a diameter of 1.27 meters and a height of 1.14 meters. Solar cells were mounted on these detachable curved panels.

Project Objectives – Measurements by instruments on the pair of spacecraft permitted ambiguities associated with the motion of near-Earth space boundaries to be resolved.

Spacecraft Payload – Use of two spacecraft, separated by a variable distance, allowed scientists to study the boundaries in near-Earth space and the nature of their fluctuation. These included the plasma pause, the magnetopause, where the magnetic field of the Earth meets that of the solar wind, the bow shock, a sort of bow wave created by the motion of the solar wind past the Earth, and several less obvious features of the Earth's magnetic tail.

Project Results – ISEE-A and -B were successfully launched on October 22, 1977 from the Kennedy Space Center, Florida. ISEE-A's orbit was 138,124 by 280.1 kilometers, inclined at 28.73 degrees and with a period of 57 hours and 26.8 minutes. ISEE-B was in a similar orbit – 138,300 by 279.4 kilometers and 28.6 degrees.

Major Participants – ISEE-A was a NASA Goddard Space Center-designed spacecraft, built, fabricated, and tested at Goddard with all of its components made either at Goddard or supplied by industries or universities. ISEE-B was an ESA – European Space Technology Center – satellite design. The STAR consortium of 10 countries supervised construction under contract to ESA. STAR consisted of industries in Belgium, Denmark, France, Spain, Germany, Italy, the Netherlands, Sweden, Switzerland, and the United Kingdom. Dornier Systems in Germany headed the contractor team.

Goddard directed the Delta rocket program for NASA's Office of Space Flight and McDonnell-Douglas Astronautics Co., Huntington Beach, California, was the prime contractor.

Key Spacecraft Personnel		Affiliation
ISEE/A		
MG	J. P. Corrigan	NASA Headquarters
PM	R. O. Wales	NASA-GSFC
SC	M. J. Aucremanne	NASA Headquarters
PS	K. W. Ogilvie	NASA-GSFC
ISEE/B		
PM	A. Hawkyard	ESA-ESTEC
PS	A. C. Durney	ESA-ESTEC
CO	G. E. Kowalski	NASA-GSFC
MG	J. R. Holtz	NASA Headquarters
SC	E. R. Schmerling	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
ISEE/A			
Fast Plasma + Solar Wind Ion	PI	S. J. Bame	Los Alamos Scientific Laboratory
	OI	H. Miggenrieder	MPI-Extraterrestrial Physics
	OI	K. Schindler	Ruhr University Bochum
	OI	J. R. Asbridge	Los Alamos Scientific Laboratory
	OI	H. R. Rosenbauer	MPI- Aeronomy
	OI	H. Volk	MPI-Nuclear Physics
	OI	M. D. Montgomery	Los Alamos Scientific Laboratory
	OI	G. Paschmann	MPI-Extraterrestrial Physics
	OI	W. C. Feldman	Los Alamos Scientific Laboratory
	OI	E. W. Hones, Jr.	Los Alamos Scientific Laboratory
Fast Electrons	PI	K. W. Ogilvie	NASA-GSFC
	OI	J. D. Scudder	NASA-GSFC
Hot Plasma	PI	L. A. Frank	University of Iowa
	OI	V. M. Vasyliunas	MPI-Aeronomy
	OI	C. F. Kennel	University of California, Los Angeles
Fluxgate Magnetometer	PI	C. T. Russell	University of California, Los Angeles
	OI	R. L. McPherron	University of California, Los Angeles
	OI	P. C. Hedgecock	Imperial College
	OI	E. W. Greenstadt	TRW Systems Group
	OI	M. G. Kivelson	University of California, Los Angeles

Experiment	Experiment Personnel		Affiliation
Low Energy Cosmic Rays	OI	J. J. O'Gallagher	University of Maryland
	PI	D. K. Hovestadt	MPI-Extraterrestrial Physics
	OI	M. Scholer	MPI-Extraterrestial Physics
	OI	L. A. Fisk	University of New Hampshire
	OI	C. Y. Fan	University of Arizona
	OI	G. Gloeckler	University of Maryland
Quasi-Static Electric Field	OI	M. C. Kelley	University of California, Berkeley
	PI	F. S. Mozer	University of California, Berkeley
Plasma Waves	PI	D. A. Gurnett	University of Iowa
	OI	F. L. Scarf	TRW Systems Group
	OI	R. W. Fredericks	TRW Systems Group
	OI	E. J. Smith	NASA-JPL
Plasma Density	OI	M. Petit	CNET
	OI	J. R. McAfee	NOAA-ERL
	OI	D. Jones	ESA-ESTEC
	OI	J. M. Etcheto	CNET
	PI	C. C. Harvey	Paris Observatory
	OI	R. J. L. Grard	ESA-ESTEC
	OI	R. E. Gendrin	CNET
Energetic Electric and Protons	PI	D. J. Williams	NOAA-ERL
	OI	C. O. Bostrom	Applied Physics Laboratory
	OI	B. Wilken	MPI-Aeronomy
	OI	T. A. Fritz	NOAA-ERL
	OI	G. H. Wibberenz	University of Kiel
	OI	E. Keppler	MPI-Aeronomy
Electrons and Protons	OI	C. I. Meng	Applied Physics Laboratory
	PI	K. A. Anderson	University of California, Berkeley
	OI	F. V. Coroniti	University of California, Los Angeles
	OI	J. M. Bosqued	CESR
	OI	R. Pellat	Center for Theoretical Physics
	OI	G. K. Parks	University of Washington
	OI	R. P. Lin	University of California, Berkeley
	OI	H. Reme	CESR
DC Electric Fields	PI	J. P. Heppner	NASA-GSFC
	OI	T. L. Aggson	NASA-GSFC
	OI	N. C. Maynard	NASA-GSFC
	OI	D. A. Gurnett	University of Iowa
	OI	D. P. Cauffman	Lockheed, Palo Alto

Experiment	Experiment Personnel	Affiliation
Ion Composition	PI R. D. Sharp	Lockheed, Palo Alto
	OI G. Haerendel	MPI-Extraterrestrial Physics
	OI H. R. Rosenbauer	MPI-Aeronomy
	OI R. G. Johnson	Lockheed, Palo Alto
	OI E. G. Shelley	Lockheed, Palo Alto
	OI J. Geiss	University of Berne
	OI P. X. Eberhardt	University of Berne
	OI H. Balsiger	University of Berne
	OI C. R. Chappell	NASA-MSFC
	OI A. Ghielmetti	University of Berne
	OI D. T. Young	University of Berne
VLF Wave Propagation	PI R. A. Helliwell	Stanford University
	OI T. F. Bell	Stanford University
Gamma-Ray Bursts	OI D. K. Hovestadt	MPI-Extraterrestrial Physics
	OI B. J. Teegarden	NASA-GSFC
	PI T. L. Cline	NASA-GSFC
	OI G. Gloeckler	University of Maryland

Experiment	Experiment Personnel	Affiliation
ISEE/B		
Fast Plasma	OI W. C. Feldman	Los Alamos Scientific Laboratory
	OI E. W. Hones, Jr.	Los Alamos Scientific Laboratory
	OI K. Schindler	Ruhr University Bochum
	PI G. Paschmann	MPI-Extraterrestrial Physics
	OI H. Miggenrieder	MPI-Extraterrestrial Physics
	OI S. J. Bame	Los Alamos Scientific Laboratory
	OI H. Volk	MPI-Nuclear Physics
	OI H. R. Rosenbauer	MPI-Aeronomy
	OI M. D. Montgomery	Los Alamos Scientific Laboratory
	OI J. R. Asbridge	Los Alamos Scientific Laboratory
Solar Wind Ions	PI G. Moreno	CNR, Space Plasma Laboratory
	OI P. Cerulli	CNR, Space Plasma Laboratory
	OI V. Formisano	CNR, Space Plasma Laboratory
	OI A. Egidi	CNR, Space Plasma Laboratory

Experiment	Experiment Personnel		Affiliation
	OI	S. C. Cantarano	CNR, Space Plasma Laboratory
	OI	S. J. Bame	Los Alamos Scientific Laboratory
	OI	G. Paschmann	MPI-Extraterrestrial Physics
Hot Plasma	PI	L. A. Frank	University of Iowa
	OI	V. M. Vasyliunas	MPI-Aeronomy
	OI	C. F. Kennel	University of California, Los Angeles
Fluxgate Magnetometer	PI	C. T. Russell	University of California, Los Angeles
	OI	R. L. McPherron	University of California, Los Angeles
	OI	P. C. Hedgecock	Imperial College
	OI	E. W. Greenstadt	TRW Systems Group
	OI	M. G. Kivelson	University of California, Los Angeles
Plasma Waves	PI	D. A. Gurnett	University of Iowa
	OI	F. L. Scarf	TRW Systems Group
	OI	F. J. Smith	NASA-JPL
	OI	R. W. Fredericks	TRW Systems Group
Radio Propagation	OI	R. E. Gendrin	CNET
	OI	J. R. McAfee	NOAA-ERL
	OI	M. Petit	CNET
	OI	D. Jones	ESA-ESTEC
	OI	J. M. Etcheto	CNET
	PI	C. C. Harvey	Paris Observatory
	OI	R. J. L. Grard	ESA-ESTEC
Energetic Electrons and Protons	PI	D. J. Williams	NOAA-ERL
	OI	T. A. Fritz	NOAA-ERL
	OI	C. A. Bostrom	Applied Physics Laboratory
	OI	E. Keppler	MPI-Aeronomy
	OI	B. Wilken	MPI-Aeronomy
	OI	G. H. Wibberenz	University of Kiel
Electrons and Protons	OI	C. I. Meng	Applied Physics Laboratory
	OI	J. M. Bosqued	CESR
	OI	R. Pellat	Center for Theoretical Physics
	OI	F. V. Coroniti	University of California, Los Angeles
	PI	K. A. Anderson	University of California, Berkeley
	OI	H. Reme	CESR
	OI	R. P. Lin	University of California, Berkeley
	OI	G. K. Parks	University of Washington

METEOSAT

Launch Vehicle – Delta 2914.

Spacecraft Description – Main structure was 2.10 meters (7 feet) in diameter, 3.2 meters (10.4 feet) high and weighed 697 kilograms (1,535 pounds) at launch and more than 700 pounds in orbit. The spin-stabilized vehicle rotated at 100 rpm.

Project Objectives – One of five space platforms for gathering integrated meteorological data for use in the Global Weather Experiment, a part of the Global Atmospheric Research Program.

Spacecraft Payload – High-resolution radiometer with definition of 2.5 km in the visible (daylight) band and 5 km in infrared. The radiometer produced line-scan images using the spacecraft's rotation with a full picture building up every 30 minutes.

Project Results – Launched from Cape Kennedy November 22, 1977 into a synchronous equatorial orbit at 0 degrees longitude, 0 degrees latitude (over the west coast of South Africa).

Major Participants – Spacecraft management, European Space Agency; spacecraft prime contractor, Aerospatiale, acting as lead for the European COSMOS consortium; launch vehicle management, NASA-Goddard Space Flight Center; launch operations, NASA-Kennedy Space Center; launch vehicle prime contractor, McDonnell Douglas.

Key Spacecraft Personnel		Affiliation
PS	D. Lennertz	ESA-ESTEC
PM	M. Delahais	ESA-ESTEC

Experiment	Experiment Personnel		Affiliation
Imaging Radiometer	PI	ESA Staff	ESA-ESTEC
	CO	M. Reynolds	ESA-ESTEC
Data Collection Platform (DCP)	PI	ESA Staff	ESA-ESTEC
	CO	M. Reynolds	ESA-ESTEC

SAKURA (CS)

Launch Vehicle – Straight-Eight Delta. Five stage thrust was 205,000 pounds. Carried nine strap-on solid propellant motors on first stage. Each Castor II solid generated 52,000 pounds of thrust. The second stage produced 9,800 pounds of thrust and was capable of restarting. It used a version of the Apollo Lunar Module Descent Engine developed by TRW for the moon-landing program. The third stage used a Thiokol solid motor that generated 14,100 pounds of thrust.

Spacecraft Description – CS was more than 351 centimeters long and 218 cm in diameter. The satellite weighed approximately 676 kilograms at liftoff and 340 kg once injected into geosynchronous orbit.

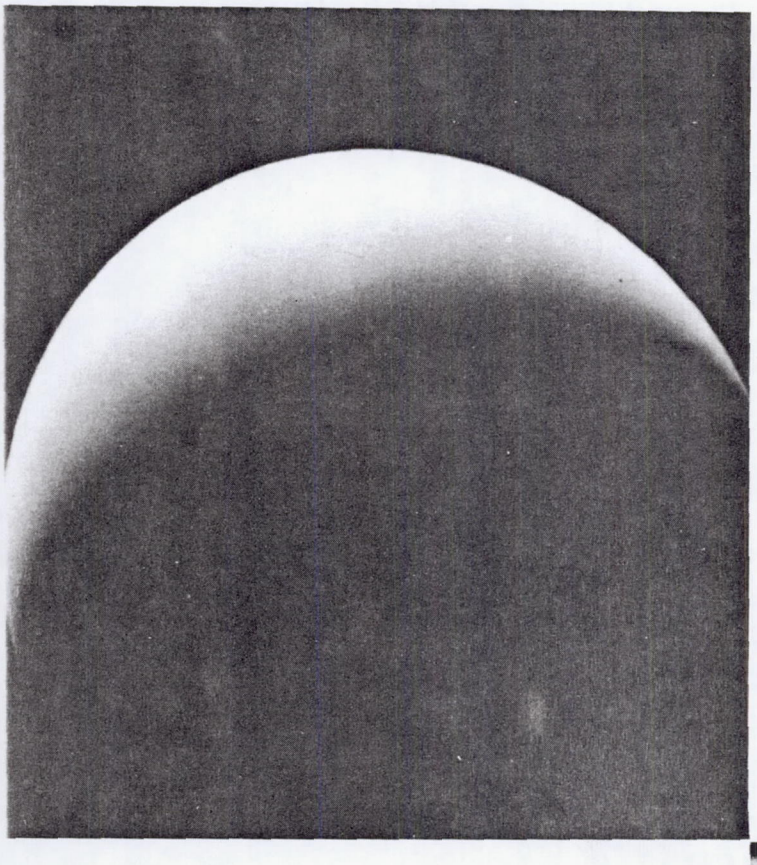
Project Objectives – Designed to relay television and telephone signal distribution throughout the islands. CS was the first to operate in the 20 to 30 GHz range (K-band). Experiments were conducted in this band to determine its suitability for operational communications systems.

Spacecraft Payload – The Japanese satellite was equipped with six K-band and two C-band communications transponders for relay of communications and television signals. Primarily powered by more than 20,000 solar cells which covered the cylindrical main body, augmented by a battery for eclipse mode operation. The solar array provided over 500 watts of power.

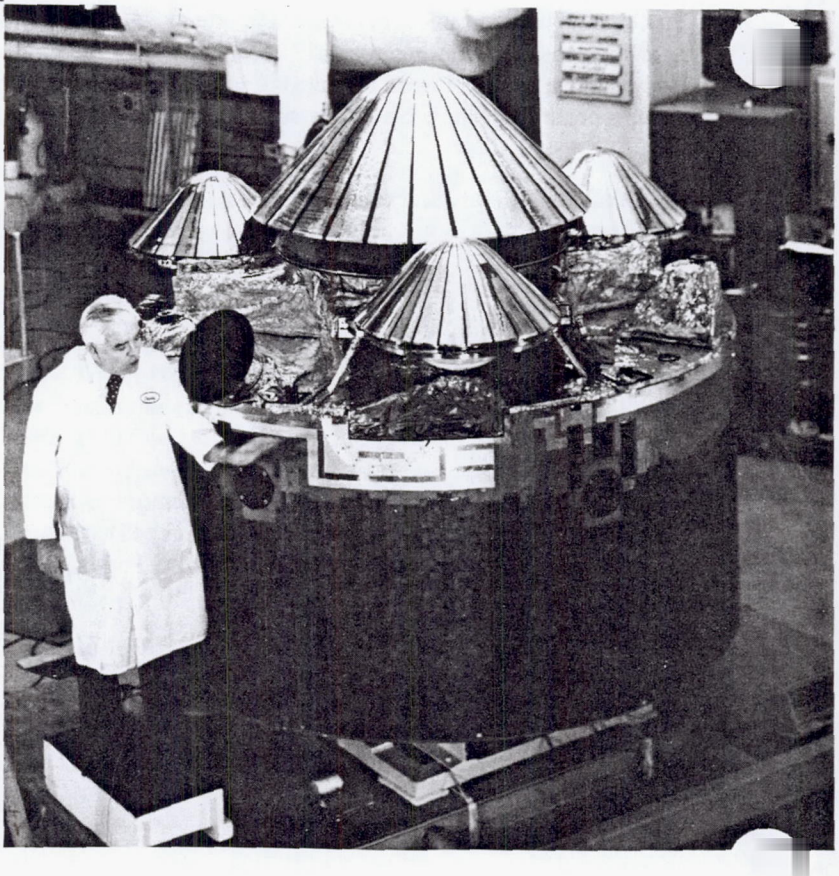
Earth sensors aboard the CS were used as a reference for maintaining pointing of the communications antenna. The main body of the satellite spun at 90 rpm, and acted as a gyroscope to provide stability. Thrusters using monopropellant hydrazine provided attitude and station-keeping capability.

Project Results – CS was successfully launched on December 14, 1977 from NASA's Kennedy Space Center, Florida into geosynchronous orbit aboard a Delta launch vehicle.

Major Participants – The CS was a communications satellite program of the National Space Development Agency of Japan (NASDA). NASDA was responsible for the satellite's procurement, launch, and initial checkout. The CS was designed, developed, and manufactured by Mitsubishi Electric Corporation and Ford Aerospace and Communications Corp. The satellite was used by the Japanese Ministry of Post and Telecommunications and by NASDA for experimental use. Prime contractor for the Delta launch vehicle was McDonnell Douglas Astronautics Co., Huntington Beach, California.

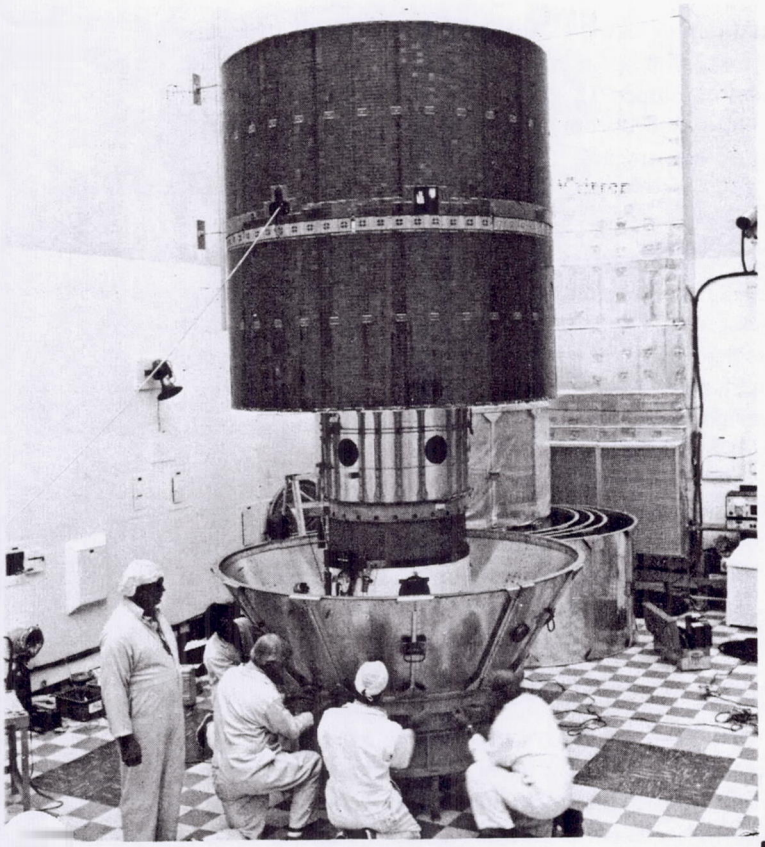


Crescent of Venus illuminated by sunlight during early morning of Venus day. This is the first picture taken by the cloud photopolarimeter of Pioneer Venus Orbiter, launched on May 20, 1978.

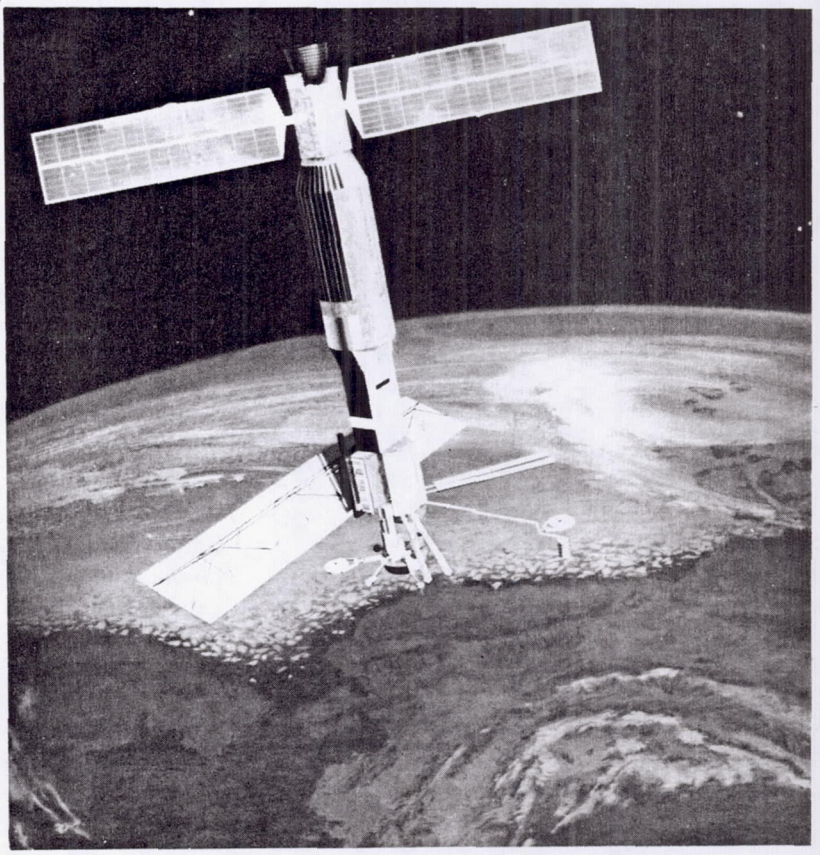


Pioneer-Venus project manager Charles Hall stands next to the thermal model of the spacecraft that carried four probes to Venus. Launched August 8, 1978, these probes – in conjunction with Pioneer-Venus-A, launched on May 20, 1978 – carried out scientific studies of the planet's weather, atmosphere, etc. These probes were to be released twenty days before impacting on Venus.

1978

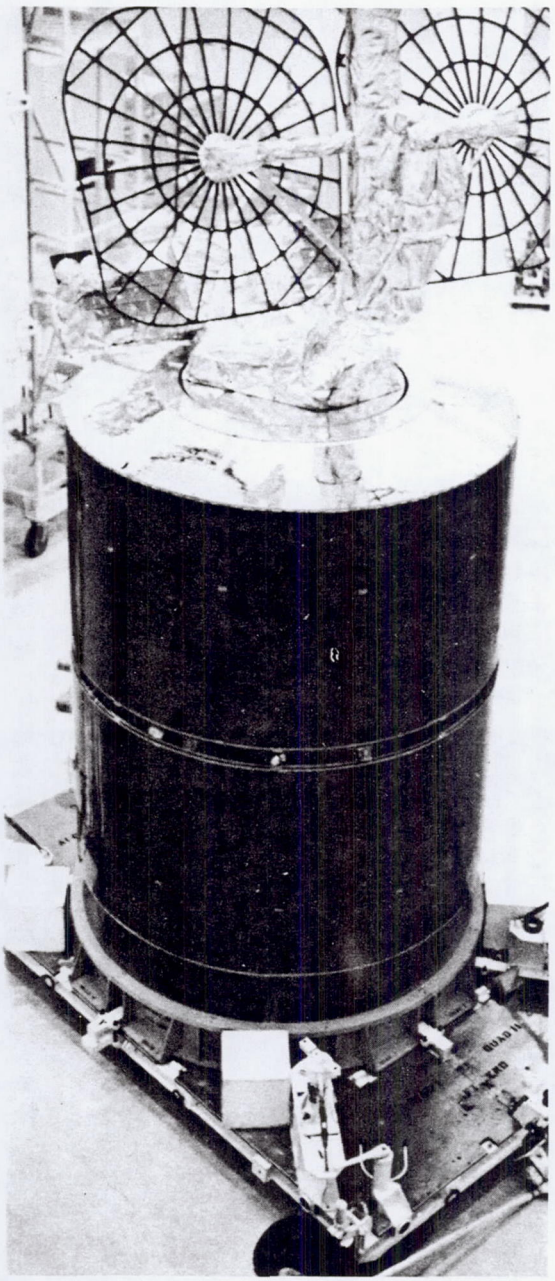


NATO-III C, the third and final communications satellite in a new series serving the North Atlantic Treaty Organization. The satellite was launched from Cape Canaveral on November 19, 1978.



Artist's sketch of SEASAT-A spacecraft as it studied oceans from Earth orbit. The satellite was to circle the globe 14 times a day, providing coverage of 95 percent of the oceans every 36 hours.

INTELSAT IVA
Flight 3 and Flight 6



NTELSAT IVA F-6 prior to encapsulation.

Launch Vehicle – Atlas Centaur AC-48. The Atlas Centaur, 40.8 meters high at liftoff, weighed 148,060 kilograms including the spacecraft. The first stage Atlas booster developed 1,920 kilonewtons of thrust at liftoff using an MA-5 system of two thrust booster engines, one thrust sustainer engine, and two thrust vernier engines.

Spacecraft Description – Drum-shaped, spin-stabilized main body 2.85 meters high and 2.4 meters in diameter. The antenna array brought the total height to 6.98 meters. Solar arrays covering the sides of the main body provided approximately 600 watts of power. Solid propellant apogee motor mounted in the base of the cylinder provided 10,000 pounds of thrust. Antennas were mounted on a despun platform atop the cylinder. Weight at launch was 1,480 kg; in orbit, 825.5 kg.

Project Objectives – Provide increased telecommunications capacity for Intelsat's global network. Intelsat IVA's were to serve as replacements of earlier spacecraft. The Intelsat system provided more than half of the world's transoceanic international telecommunications services.

Spacecraft Payload – A 20-transponder system employing frequency reuse and new antennas provided at least 6,250 telephone circuits and two TV channels. Mechanically despun platform supported twin 1.36 meter dish transmit antennas. The receive antenna used two sets of feedhorns working in conjunction with a third dish reflector. Each transponder had a bandwidth of 36 MHz. Intelsat IVA's had the capability to switch two of its narrow beam channels to wide beam channels to cover the large number of countries it serves.

Project Results – Intelsat IVA Flight 3 was launched on January 7, 1978. It was in geostationary orbit at a point over the Indian Ocean, 60 degrees east longitude. Apogee was 35,704 km; perigee was 35,780 km. Intelsat IVA Flight 6 was launched on March 31, 1978. It was also in geostationary orbit over the Indian Ocean at 63 degrees east longitude. Apogee of IVA-F6 was 35,851 km, and perigee was 35,730 km. IVA Flight 3 served as a back-up to IVA Flight 6. Each satellite had a design life of seven years.

Major Participants – The Intelsat IVA satellites were built by Hughes Aircraft Company, El Segundo, California. The Communications Satellite Corporation (COMSAT), the United States member of the International Telecommunications Satellite Organization (INTELSAT), was the spacecraft manager. NASA's Lewis Research Center, Cleveland, Ohio had management responsibility for Atlas Centaur development and operation. General Dynamics/Convair constructed the Atlas Centaur launch vehicle and Rocketdyne Division of Rockwell International Corporation, Canoga Park, California built the MA-5 propulsion system.

INTERNATIONAL ULTRAVIOLET EXPLORER (IUE-A)

Launch Vehicle – Delta 318. A three-stage Delta with an overall length of approximately 35 meters. The first stage was a modified Thor booster incorporating nine Castor II strap-on Thiokol solid fuel rocket motors.

Spacecraft Description – The IUE-A was an octagonal structure with the telescope protruding from the top and a fixed solar array on two opposite sides. It was 4.3 meters high and 1.3 meters in diameter at launch. With the solar array unfolded in space, it was 4.3 m wide. Total weight of the IUE was 671 kg, including the apogee boost motor.

Project Objectives – IUE-A was a joint project of NASA, ESA, and Britain's Science Research Council. Carrying a large telescope, spectrographs, and UV-sensitive television cameras, the IUE was controlled in real-time by astronomers at NASA's Goddard Space Flight Center in Greenbelt, Maryland and at ESA's Villafranca del Castillo ground station, 30 km west of Madrid.

It was designed to examine the ultraviolet spectral region between 1150 and 3200 Angstroms, a region inaccessible from telescopes on Earth. This region included the fundamental emissions of many of the common elements in the universe (e.g., hydrogen, helium, carbon, oxygen). Studies included the solar system and distant objects in the universe including quasars, pulsars, and black holes.

Spacecraft Payload – The 45 cm diameter, f/15, Cassegrain telescope provided point-source images of about 1 arc-sec on-axis at its focal plane. The useful field of view was 16 minutes of arc in diameter. Light from the telescope was analyzed by either of two spectrographs with a resolution of about 0.1A. Each of the two spectrographs incorporated two UV-sensitive television cameras. The cameras were operated in a digital mode, using a 256-level gray scale, permitting accurate measurements of intensity by each camera of more than 1/2 million picture elements. The video data were transmitted to the ground stations to be computer-processed.

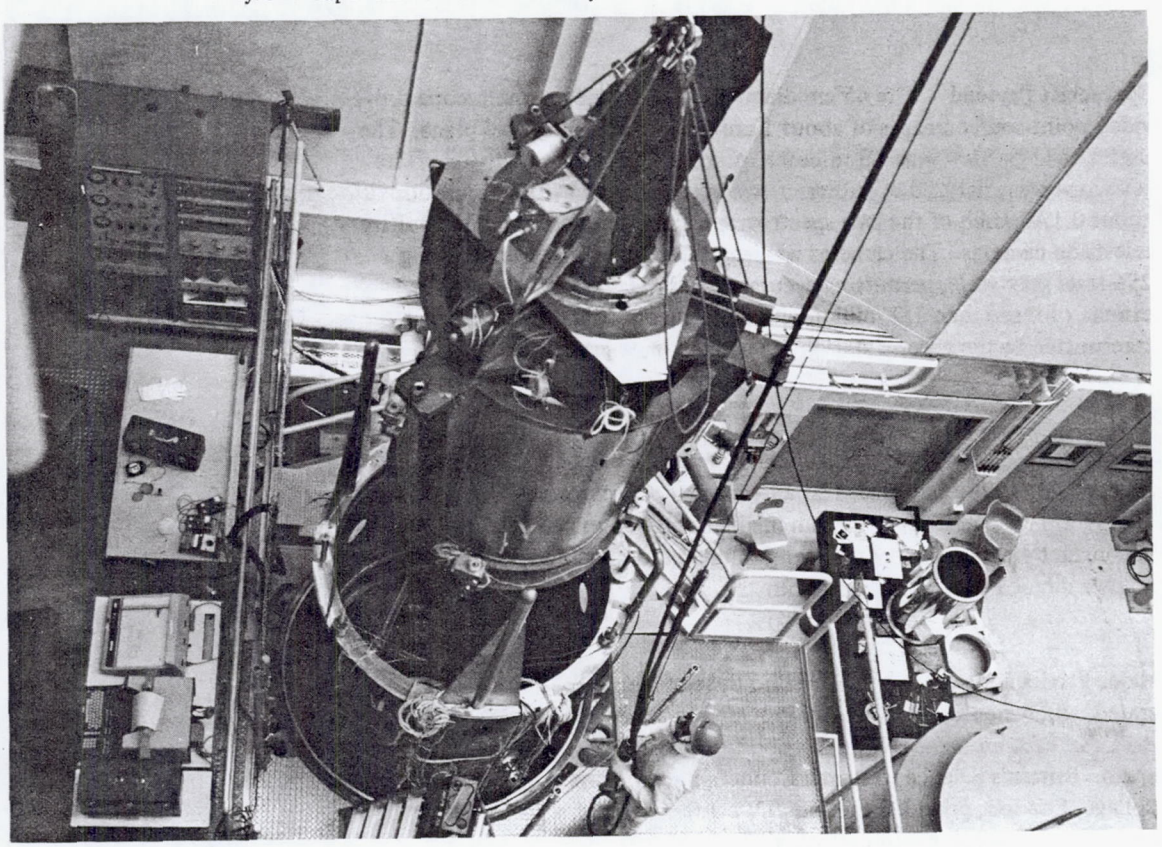
Project Results – IUE-A was launched from Cape Canaveral, Florida, on January 26, 1978, and placed in an eccentric, synchronous Earth orbit, 45,859 km by 25,722 km, with an inclination of about 29 degrees. It was in constant view from the Goddard ground station, and in view at least 10 hours a day from the Madrid station.

Major Participants – NASA's Goddard Space Flight Center designed, integrated, and tested the IUE-A, and provided the ground support facility in the U.S. ESA built the solar array and the ground facilities near Madrid, Spain. Britain's Science Research Council, in collaboration with University College, London, provided the four TV camera detectors for transforming the spectral displays into video signals.

Key Spacecraft Personnel		Affiliation
PM	G. Longanecker	NASA-GSFC
PS	A. Boggess, III	NASA-GSFC
SC	N.G. Roman	NASA Headquarters
MG	M.J. Aucremanne	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Ultraviolet Spectrograph	CO	A. Boggess, III	NASA-GSFC
	CO	A. B. Underhill	NASA-GSFC
	CO	N. G. Roman	NASA Headquarters
Particle Flux Monitor	CO	C. O. Bostrom	Applied Physics Laboratory

NASA in cooperation with the European Space Agency and the United Kingdom's Science Research Council built this IUE at Goddard Space Flight Center. It was launched from Cape Canaveral on January 26, 1978.



NAVY FLEET SATELLITE COMMUNICATIONS FLTSATCOM-A

Launch Vehicle – Atlas-Centaur. Two-stage, liquid-fueled vehicle. First stage was an Atlas vehicle, 21.3 m long, with a MA-5 engine system developing 1,917,288 Newtons at liftoff. The Centaur second stage was 14 m long; its two engines produced 133,400 Newtons.

Spacecraft Description – The basic FLTSATCOM consisted of two stacked hexagonal modules, antennas, and two winglike solar arrays. The hexagonal body was 2.4 meters across and stood 1.27 m high. At launch, the satellite weight was 1,884 kg; in-orbit weight: 987 kg. It had an 18-turn helical UHF receive antenna and a 4.8 meter deployable parabolic UHF transmit antenna. The solar array provided 1,200 watts of power. Three-axis stabilization was provided by redundant, body-mounted momentum wheels that interacted with monopropellant hydrazine thrusters to stabilize the spacecraft's attitude and point the antennas at the Earth's center.

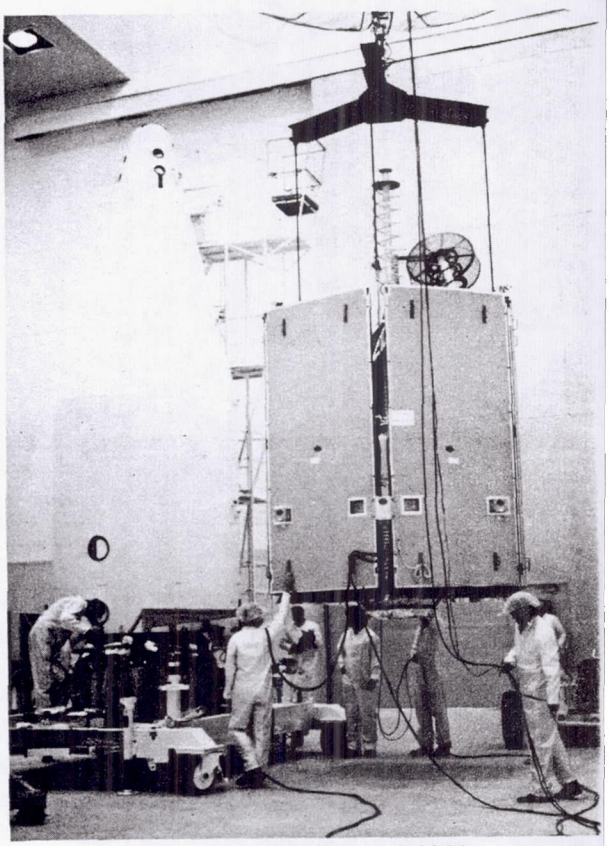
Project Objectives – The FLTSATCOM system was designed to provide worldwide high-priority UHF communications between naval aircraft, ships, submarines and ground stations, SAC and the Presidential command network. The communications subsystem provided more than 30 voice and 12 teletype channels designed to serve small mobile users such as ships, aircraft, and mobile ground units. The design life was five years. Operation in the UHF band permitted the use of simple aircraft and submarine antennas with hemispheric coverage patterns, thus eliminating the need for satellite tracking.

Spacecraft Payload – The payload module of the satellite included the UHF and SHF communications equipment and antennas. The communications system provided these relay links: one 25 kHz fleet broadcast channel and SHF beacon, nine 25 kHz fleet relay channels, twelve 5 kHz Air Force narrowband channels, and one 500 kHz DoD wideband channel. The UHF receive band covered the 292 to 400 MHz range and the transmitted signals were in the 244 to 279 MHz band.

Project Results – FLTSATCOM-A was launched on February 9, 1978 from Cape Canaveral, Florida. After achieving an elliptical transfer orbit with an apogee of approximately 19,300 nmi, the satellite separated from the launch vehicle. The apogee kick motor (AKM) was fired to inject the satellite into a near equatorial, near-synchronous drift orbit. On March 16, 1978 the satellite drift was halted by a stop maneuver at the operational site of 100 degrees west longitude. Inclination was 2.6 degrees; apogee: 35,818 km (22,249 mi); perigee: 25,753 km.

Major Participants — The satellite was built by TRW Defense and Space Systems Group in Redondo Beach, California. The Naval Electronics Systems Command is managing the overall FLTSATCOM program. The Air Force System Command's Space and Missile Systems Organization (SAMSO) is acquiring the space segment. Launch vehicle contractor was General Dynamics; Lewis Research Center, launch vehicle management.

The U.S. Navy's FLTSATCOM-A undergoing balancing and testing prior to launch from Cape Canaveral, Florida.



1978

LANDSAT-C

Launch Vehicle – Delta 2910. Two-stage launch vehicle, 35.3 meters tall, with a diameter of 2.44 m, not including the strap-on motors.

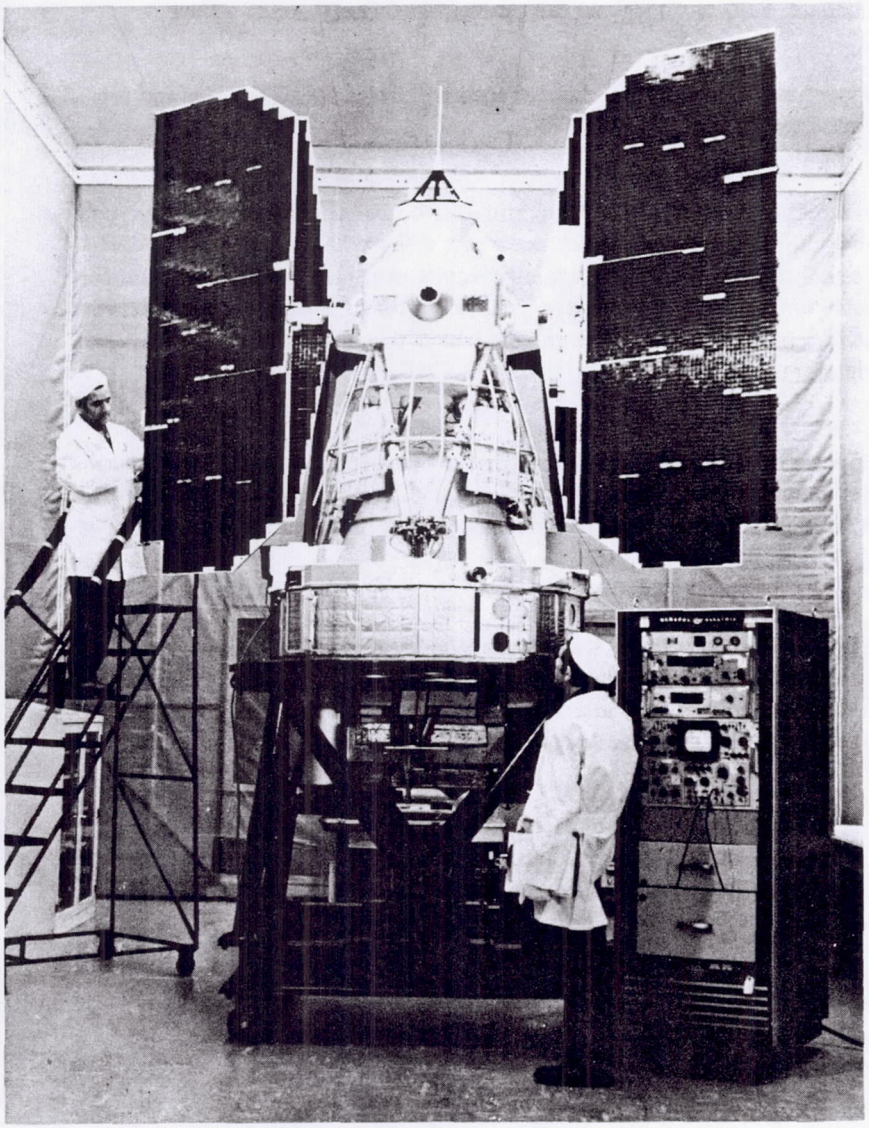
Spacecraft Description – Landsat-C was 3.04 m high and, with its two butterfly-wing shaped solar panels extended, measured 3.96 m across. It weighed 940 kg (2,073 lb.) and was Earth-oriented and three-axis stabilized for high-resolution remote sensing from space.

Project Objectives – Acquisition of multispectral, repetitive data of the surface of the Earth, acquisition of surface temperatures from the thermal infrared channel, research on remote sensors for earth resources observation, high resolution geographic mapping, and data interpretation and analysis. AMSAT-OSCAR 8 piggybacked this mission.

Spacecraft Payload – Two Return Beam Vidicon cameras viewed two side by side, 50 nautical mile-square scenes directly beneath the spacecraft. RBV cameras were reshuttered every 12.5 seconds to produce overlapping images. Each camera had a panchromatic spectral response of 0.505 to 0.75 micrometers (green to the near infrared). Each camera had a ground resolution of 40 meters. A Multispectral Scanner Subsystem (MSS) collected data by continually scanning the surface directly beneath the spacecraft. Each MSS image covered an area measuring 185 km on a side, for a total area of 34,225 square km. Five spectral bands were monitored continuously, four collected solar-reflected energy in spectral bands ranging from 0.5 to 1.1 micrometers in wavelength (blue, green, infrared, and near-infrared). The fifth channel operated in the thermal infrared region from 10.4 to 12.6 micrometers, collecting emitted thermal energy rather than solar reflected energy. A Data Collection System carried by the satellite collected data from up to 1,000 remote, automated sensor platforms located within the North American continent. These platforms measured such parameters as soil, water, and air quality, temperature, stream flow, and snow depth. Landsat 3-C relayed these data twice a day to the Goddard Space Flight Center when the spacecraft was in simultaneous view of the continuously transmitting platform and a data acquisition station. Landsat 3-C also had two wide band video tape recorders which stored images when the satellite was not within range of one of the ground stations for later playback.

Project Results – Landsat 3-C was launched from Vandenberg AFB, California, on March 5, 1978. In a near polar, sun-synchronous orbit with an inclination of 99.1 degrees, its apogee was 914 km and its perigee was 890 km.

Major Participants – The spacecraft prime contractor was General Electric Company, Space Division. GE also designed the spacecraft wideband video tape recorders and was responsible for the ground data handling system. The RBV system was constructed by the Astro-Electronics Division of RCA, Princeton, New Jersey. Hughes Aircraft Company, El Segundo, California constructed the Multispectral Scanner subsystem. The Delta launch vehicle was constructed by McDonnell Douglas in Huntington Beach, California. Project management was the responsibility of the NASA-Goddard Space Flight Center.



Landsat-C was designed to study the Earth's natural resources. For the first time one of its cameras was to measure such natural resources as water, agricultural fields and mineral deposits in total darkness.

Key Spacecraft Personnel		Affiliation
MG	B. T. Nolan	NASA Headquarters
PM	C. M. Mackenzie	NASA-GSFC
PS	S. C. Freden	NASA-GSFC
SC	R. I. Whitman	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Return Beam Vidicon System	PI	L. Wilson	NASA-GSFC
Multispectral Scanner	PI	J. A. Balla	NASA-GSFC
Data Collection System	PI	E. L. Gilbert	NASA-GSFC

ORBITING SATELLITE CARRYING AMATEUR RADIO (OSCAR-8)

Launch Vehicle – Piggybacked on Landsat-C Delta launch vehicle.

Spacecraft Description – Cube-shaped with solar panels on sides and top of satellite. Weight: 27 kg (60 lb.).

Project Objectives – The principal objective of OSCAR-8 was to expand educational programs into classrooms across the U.S. and Canada. Additional objectives included providing continuous radio communications for a wide range of experiments, particularly with small amateur ground stations and terminals, for mobile communications with aeronautical, maritime, and land units.

Spacecraft Payload – OSCAR-8 carried two transponders for amateur radio communications. Both transponders used the same uplink frequency of 145.9 MHz, but employed different downlink frequencies of 29.4 MHz and 435.1 MHz.

Project Results – OSCAR-8 was launched as a piggyback payload by NASA aboard the Delta launch vehicle that successfully launched Landsat-C on March 5, 1978. It was in a sun-synchronous, near polar orbit with an inclination of 98.9 degrees. Apogee was 915 km and perigee was 904 km.

Major Participants – The spacecraft was built by radio amateurs in the U.S., Canada, West Germany, and Japan, under the auspices of the Radio Amateur Satellite Corporation in cooperation with the American Radio Relay League, Inc.

BROADCASTING SATELLITE/ EXPERIMENTAL (BSE) Japan

Launch Vehicle – Delta 2914 – three-stages with a height of 21.3 meters (70 ft.) including a shroud. Maximum diameter was 2.4 m (8 ft.) and total liftoff weight was 131,895 kg (293,100 lb.). Liftoff thrust was 1,765,315 newtons (396,700 lb.) including strap-on solids. The first stage was a combination liquid fuel and strap-on solid propellant motors.

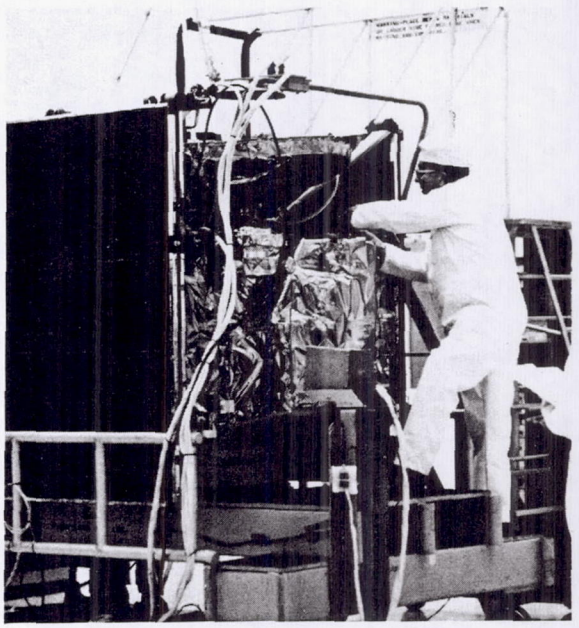
Spacecraft Description – Box-shaped, three-axis stabilized satellite weighing 677.7 kg (1,494 lb.).

Project Objectives – This experimental Japanese TV spacecraft tested new methods of transmitting high quality color television economically to the Japanese islands and Okinawa. BSE was to transmit directly to individual, low cost, home TV sets.

Spacecraft Payload – High-power, high-capacity communications/broadcast system to provide video transmissions to 1 to 1.6 meter ground antennas.

Project Results – BSE was launched from Cape Canaveral, Florida on April 7, 1978. On its third apogee, 26.6 hours after launch, a motor attached to the satellite was fired by Japan's National Space Development Agency (NASDA) to place the spacecraft in its final synchronous orbit. The inclination was 0.0 degrees; apogee was 35,661 km, and perigee was 35,114 km. The spacecraft drifted to its final position of 110 degrees East longitude over the Equator near Borneo.

Major Participants – The BSE was built by General Electric Company, Valley Forge, Pennsylvania, under contract to Tokyo Shibaura Electric Company for NASDA. NASA's worldwide Spaceflight Tracking and Data Network (STDN) tracked the spacecraft for the first few orbits until NASDA injected the BSE into its final orbit. Thereafter, NASDA assumed all tracking responsibility. Also sponsoring or participating in the program were the Japanese Broadcasting Corporation (NHK), the Japanese Ministry of Post and Telecommunications (MPOT), and the Radio Research Laboratories (RRL) of Japan. The Delta project was managed for NASA's Office of Space Transportation Systems by Goddard Space Flight Center, Greenbelt, Maryland. Prime contractor for Delta was McDonnell Douglas Astronautics Corporation, Huntington Beach, California.



Japan's BSE, the Japanese experimental satellite, undergoes prelaunch testing.

1978

APPLICATIONS EXPLORER MISSION (AEM-A) Heat Capacity Mapping Mission

Launch Vehicle – Four-stage Scout-D. The Scout was the only U.S. launch vehicle which used solid propellant exclusively. It was 22.86 m long and 1.01 m at its widest cross section. Gross weight of the launch vehicle, excluding the satellite, was 20,181 kg at liftoff.

Spacecraft Description – The HCMM was a modular design spacecraft with an overall height, including antenna, of 161.85 cm. Total weight was 134.3 kg (296.1 lb.). The spacecraft structure primarily consisted of two major components: an instrument module containing a heat capacity mapping radiometer and supporting equipment, and the spacecraft base module, containing data handling, power supply, communications and command, and attitude control subsystems.

Project Objectives – The HCCM was the first spacecraft built to test the feasibility of measuring variations in the Earth's temperatures. It acquired visible and infrared (IR) images of the Earth's surface at a scale of 1:4,000,000 (approximately 23 cm^2 for 700 km^2 frame) for investigations in geology, plant stress, soil moisture, and hydrology. The spacecraft was designed to make measurements of near maximum and minimum surface temperatures occurring during the diurnal cycle (1:30 p.m. and 2:30 a.m.) in the middle northern latitudes. Heat capacity, or the capability to retain heat (thermal inertia) was estimated from the satellite measurements.

Spacecraft Payload – The Earth-pointing heat capacity mapping radiometer was a modified surface composition mapping radiometer similar to that flown on Nimbus 5. The HCMR had a small geometric field of view (less than 1 by 1 milliradians), high radiometric accuracy, and a swath width of 700 km. Analog data from the HCMR was transmitted to ground stations via the S-band antenna in real time when the satellite was within range of the following NASA stations: Merritt Island, Florida; Goldstone, California; Fairbanks, Alaska; Orroral, Australia; Madrid, Spain; and the Goddard Center Engineering Test Center, Greenbelt, Maryland.

Project Results – Launched on April 26, 1978 from Vandenberg AFB, California, in a circular, Sun-synchronous orbit with an apogee of 646 km and a perigee of 558 km. The inclination was 97.6 degrees. The nearly polar Sun-synchronous orbit of the HCMM permitted observations between 85 degrees north and 85 degrees south latitude at least once during the day and once during the night within a 16-day interval.

Major Participants – The instrument module, containing the HCMR, was built by the International Telephone and Telegraph Co., Ft. Wayne, Indiana. The base module was built by the Boeing Aerospace Company, Seattle, Washington. The Scout launch vehicle was built by the Vought Company, Dallas, Texas and managed by NASA's Langley Research Center, Hampton, Virginia. NASA's Goddard Space Flight Center, Greenbelt, Maryland, was responsible for the design, integration and testing of the satellite and for data processing.

Key Spacecraft Personnel		Affiliation
PM	C.L. Wagner	NASA-GSFC
MG	D.S. Diller	NASA Headquarters
PS	J.C. Price	NASA-GSFC
SC	B.B. Schardt	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Heat capacity mapping of urban heat islands	PI	T.N. Carlson	Penn State Univ.
Heat capacity mapping of freeze, planting, evaporation studies	PI	C.L. Wiegland	U.S. Dept. of Agriculture
Temperature and albedo data	PI	R.D. Jackson	U.S. Dept. of Agriculture
Great Lakes studies	PI	J.R. Schott	Capspan Corp.
Thermal sensing	PI	R.J. P. Lyon	Stanford Univ.
Seasonal thermal changes	PI	E.I. Rich	Stanford Univ.
Thermal mapping	PI	T.W. Offield	U.S. Geological Survey
Feasibility of thermal sensing	PI	A.B. Kahle	Jet Propulsion Lab
Remote water sensing	PI	D.G. Moore	Environmental Research & Technology Inc.
Tidal and snow studies	PI	D.R. Weisner	NOAA
Crop studies	PI	J.C. Harlan	Texas A&M
Thermal gradients in French channel regions	PI	P.Y. Deschamps	Univ. of Lille, France
Geological and thermal studies	PI	J.Y. Scanvic	Bureau of Geological & Mineral Research, Orleans, France
Alpine studies	PI	M. Winiger	Univ. of Berne, Switzerland
Australian range land studies	PI	M.M. Cole	Bedford College, London, England
North Sea pollution	PI	G. Fielder	Univ. of Lancaster, England
Evapotranspiration	PI	S. Galli de Paratesi	Joint Research Center of the European Communities
Thermal mapping of spanish mediterranian coast	PI	R.N. de las Cuevas	National Geographic Inst. Madrid, Spain
HCMM modelling of eastern Australia	PI	K.G. McCracken	Div. of Mineral Physics, North Ryde, Australia
Coastal investigations, Sicily and Sardinia	PI	R. Cassinis	Inst. of Geophysics of Lithosphere, Milan, Italy
Life span studies in Tasman Sea	PI	J.C. Andrews	Defence Research Centre, Adelaide, Australia
HCMM studies covering West Germany, Italy, Morocco	PI	R. Haydn	Central Lab. for Geophotogrammetry and Remote Sensing, Munich, Germany
Thermal Sensing of Canadian regions	PI	J. Cihlar	Canada Center for Remote Sensing, Ottawa, Canada

ORBITAL TEST SATELLITE-B (OTS-B)

Launch Vehicle – Delta 3914 – A three-stage vehicle with a liftoff weight of 190,630 kg, standing 35.4 meters high and with a maximum diameter of 2.4 meters. Liftoff thrust was 2,058,245 Newtons (462,714 lb.).

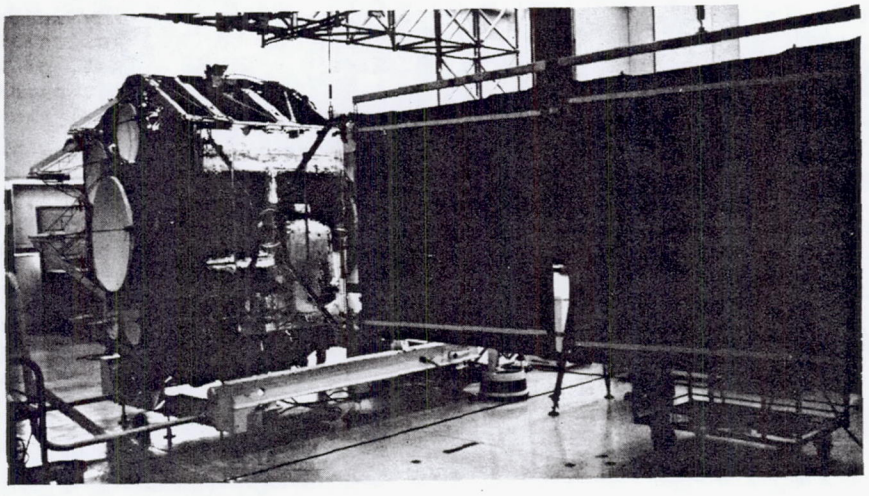
Spacecraft Description – Modular construction with two main components: a service module providing all the basic service functions, and a communications module containing the payload. Six-sided structure with large solar panel arrays attached to two opposite sides and which were deployed in orbit. Spacecraft was three-axis spin stabilized.

Project Objectives – A project of the European Space Agency, it demonstrated the performance of all on-board equipment, while providing an experimental and pre-operational traffic capacity of 6,000 telephone circuits or 4,500 telephone circuits and two television channels. From the satellite's on-station position over West Africa at 10 degrees E longitude at the Equator, coverage included the whole of western Europe, the Middle East, North Africa, the Azores, Canary Islands, Madeira, and Iceland.

Spacecraft Payload – The satellite's attitude was controlled to keep the six SHF antennas pointed towards the Earth within 0.2 degree of their assigned direction. As one of the first communications satellites operating at frequencies in the 11 and 14 GHz bands, OTS-B provided for testing simultaneously wide-band digital transmissions between large ground stations, and narrow-band signals between small stations. The in-orbit weight of the payload was 865 kg.

Project Results – OTS-B was launched from Cape Canaveral, Florida on May 11, 1978 in a synchronous, near-circular orbit, with an apogee of 35,796 km and a perigee of 35,784 km.

Major Participants — British Aerospace Dynamics Corporation was spacecraft prime contractor, supported by a team of contractors from 10 European countries. NASA's Goddard Space Flight Center, Greenbelt, Maryland, provided technical direction of the Delta project, and McDonnell Douglas constructed the Delta launch vehicle; Lewis Research Center, launch vehicle management.



The European Space Agency's orbital test satellite undergoes solar panel checkout, prior to launch on May 11, 1978.

PIONEER VENUS-A (Orbiter)

Launch Vehicle – Atlas/SLV-3D/Centaur D-1A.

Spacecraft Description – Pioneer Venus-A (Orbiter) and Pioneer Venus-B (Multiprobe) spacecraft shared a basic modular design. The basic portions of both spacecraft were their main bodies, flat cylinders, 2.5 m in diameter and 1.2 m high. These provided a spin-stabilized platform for scientific instruments and spacecraft systems. A solar array was attached to the equipment shelf. The Venus Orbiter spacecraft incorporated a despun, high-gain dish antenna on a 3-m (10 ft.) mast, and sensor elements mounted on booms. Magnetometer sensors were mounted on a three-section, deployable 4.7 m boom. Launch weight of the Orbiter was about 582 kg, with 45 kg of scientific instruments. Weight after orbital insertion was 368 kg.

Project Objectives – The two Pioneer flights to Venus were to explore the atmosphere of the planet, study its surface using radar, and determine its global shape and density distribution. Pioneer Venus A, the Orbiter, was placed in a 24-hour orbit around Venus for remote-sensing and direct measurements. At orbital low point, Orbiter came within 150 km of the surface of Venus, sampling the composition of the atmosphere and making radar measurements of the surface elevations. Daily ultraviolet and infrared pictures of the clouds and atmosphere were also taken. The spacecraft also made a variety of other remote-sensing and direct measurements of the planet and its surrounding environment. The satellite's primary mission had been selected to cover the time it takes Venus to make one revolution on its axis–243 Earth days.

Spacecraft Payload – Pioneer Venus-A carried 12 scientific instruments, all of which were mounted directly on the top side of the equipment shelf. They were: a cloud photo polarimeter, a surface radar mapper, an infrared radiometer, an airglow ultraviolet spectrometer, a neutral mass spectrometer, an ion mass spectrometer, a solar wind plasma analyzer, a magnetometer, an electric field detector, electron temperature probes, a charged particle retarding potential analyzer, and a gamma ray burst detector.

A despun, high-gain parabolic-reflector antenna focused a 7.6 degree-wide radio beam on the Earth throughout the mission. The antenna dish was 109 cm in diameter. Backup for the high-gain antenna was provided by a sleeve dipole antenna and forward and aft omni antennas. The Orbiter carried a million-bit memory and a data-handling system.

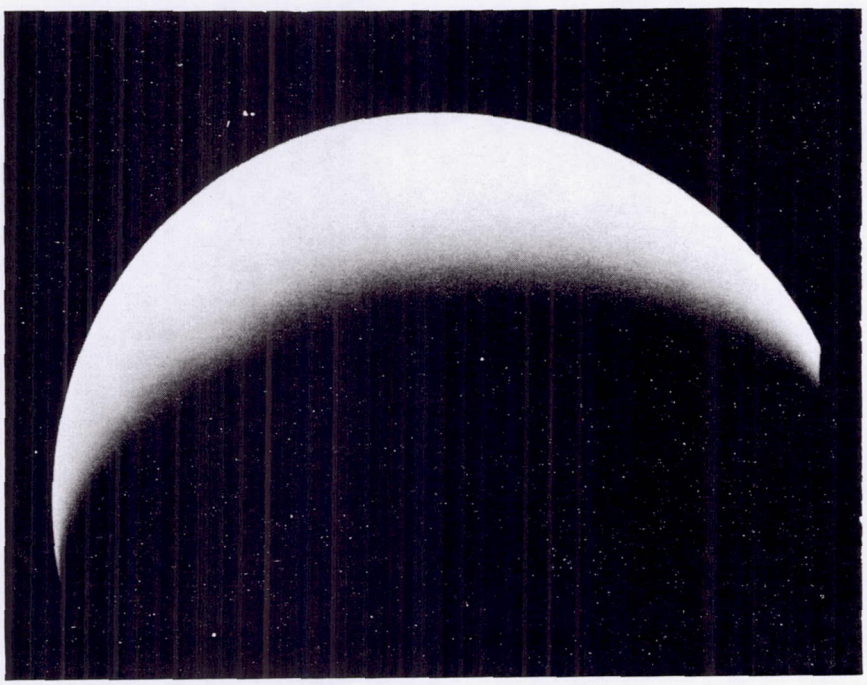
Project Results – Pioneer Venus-A was launched from Cape Canaveral, Florida, on May 20, 1978. It was injected into orbit around Venus on December 4, 1978 after completing its 300-million-mile voyage.

Major Participants – Spacecraft designed and built by Hughes Aircraft Company, El Segundo, California, under direction of NASA Ames Research Center, Mountain View, California. NASA's Deep Space Network (DSN), operated by the Jet Propulsion Laboratory, Pasadena, California, tracks and received data from Orbiter, and control and spacecraft operations were by the Pioneer Mission Operations Center in Mountain View. The launch vehicle was constructed by General Dynamics.

Key Spacecraft Personnel		Affiliation
MG	F. D. Kochendorfer	NASA Headquarters
PM	C. F. Hall	NASA-ARC
SC	R. E. Murphy	NASA Headquarters
PS	L. Colin	NASA-ARC

Experiment	Experiment Personnel		Affiliation
Langmuir Probe	OI	M. B. McElroy	Harvard University
	PI	L. H. Brace	NASA-GSFC
	OI	A. Pedersen	ESA-ESTEC
	OI	A. F. Nagy	University of Michigan
	OI	T. M. Donahue	University of Michigan
Radar Altimeter	OI	W. E. Brown, Jr.	NASA-JPL
	PI	G. Pettengill	Massachusetts Institute of Technology
	OI	W. M. Kaula	University of California, Los Angeles
	OI	D. H. Staelin	Massachusetts Institute of Technology
Radio Science Team	TL	T. A. Croft	SRI International
	TM	G. M. Keating	NASA-LARC
	TM	A. J. Kliore	NASA-JPL
	TM	R. Phillips	NASA-JPL
	TM	I. I. Shapiro	Massachusetts Institute of Technology
	TM	R. Woo	NASA-JPL
Participating Theorist	PI	T. M. Donahue	University of Michigan
Transient Gamma Ray Sources	PI	W. D. Evans	Los Alamos Science Laboratory
	OI	J. P. Conner	Los Alamos Science Laboratory
	OI	P. R. Higbie	Los Alamos Science Laboratory
	OI	R. W. Klebesadel	Los Alamos Science Laboratory
	OI	R. A. Olson	Los Alamos Science Laboratory
	OI	I. B. Strong	Los Alamos Science Laboratory
	OI	R. E. Spalding	Sandia Laboratories
Cloud Photo-polarimeter	OI	P. H. Stone	Massachusetts Institute of Technology
	PI	J. E. Hansen	NASA-GISS
	OI	A. A. Lacis	NASA-GISS
	OI	D. L. Coffeen	NASA-GISS
	OI	L. Travis	NASA-GISS

Experiment	Experiment Personnel		Affiliation
Retarding Potential Analyzer	PI	W. C. Knudsen	Lockheed Palo Alto
	OI	K. Spenner	Institute for Physics Weltraum
	OI	R. C. Whitten	NASA-ARC
Participating Theorist	PI	H. Masursky	U.S. Geological Survey
Participating Theorist	PI	G. E. McGill	University of Massachusetts
Participating Theorist	PI	A. F. Nagy	University of Michigan
Neutral Particle Mass Spectrometer	PI	H. B. Niemann	NASA-GSFC
	OI	G. R. Carignan	University of Michigan
	OI	R. E. Hartle	NASA-GSFC
	OI	N. W. Spencer	NASA-GSFC
Triaxis Fluxgate Magnetometer	PI	C. T. Russell	University of California, Los Angeles
	OI	P. J. Coleman, Jr.	University of California, Los Angeles
	OI	F. V. Coroniti	University of California, Los Angeles
	OI	C. F. Kennel	University of California, Los Angeles
	OI	R. L. McPherron	University of California, Los Angeles
	OI	G. L. Siscoe	University of California, Los Angeles



On December 7, 1978 Pioneer Venus-A obtained this crescent view of Venus, from a distance of some 65,000 kilometers.

Experiment	Experiment Personnel		Affiliation
Electric Field Detector	PI	F. L. Scarf	TRW Systems Group
	OI	I. M. Green	TRW Systems Group
Participating Theorist	PI	G. Schubert	University of California, Los Angeles
Ultraviolet Spectrometer (1100-3400A)	PI	A. I. Stewart	University of Colorado
	OI	C. A. Barth	University of Colorado
	OI	C. W. Hord	University of Colorado
	OI	G. E. Thomas	University of Colorado
	OI	D. Anderson	University of Colorado
Temperature-Sounder	PI	F. Taylor	NASA-JPL
	OI	H. H. Aumann	NASA-JPL
	OI	M. T. Chahine	NASA-JPL
	OI	C. B. Farmer	NASA-JPL
	OI	J. V. Martonchik	NASA-JPL
	OI	A. P. Ingersoll	California Institute of Technology
	OI	J. T. Houghton	Oxford University
	OI	G. D. Peskett	Clarendon Laboratory
	OI	C. D. Rodgers	Oxford University
	OI	E. J. Williamson	Clarendon Laboratory
	OI	R. E. Dickinson	National Center for Atmospheric Research
	OI	J. C. Gille	National Center for Atmospheric Research

GOES-C/NOAA

Launch Vehicle – Delta 2914.

Spacecraft Description – Cylindrical main body 2.7 m high and 1.9 m in diameter. Solar arrays provided 200 watts of primary power. The spin-stabilized spacecraft weighed about 624 kg at launch, and 295 kg in orbit. An apogee kick motor attached to the spacecraft was ejected after synchronous orbit was achieved.

Project Objectives – GOES-C was part of the Global Atmospheric Research Program sponsored by the World Meteorological Organization of the UN and the International Council of Scientific Unions. As its contribution, GOES-C gathered data from a region above the Indian Ocean, replacing GOES-A which was moved to a new location.

Spacecraft Payload – Visible/Infrared spin-scan radiometer provided day and night weather pictures. A Data Collection System on the spacecraft received and relayed environmental data sensed by widely dispersed surface platforms such as river and rain gauges and automatic weather stations.

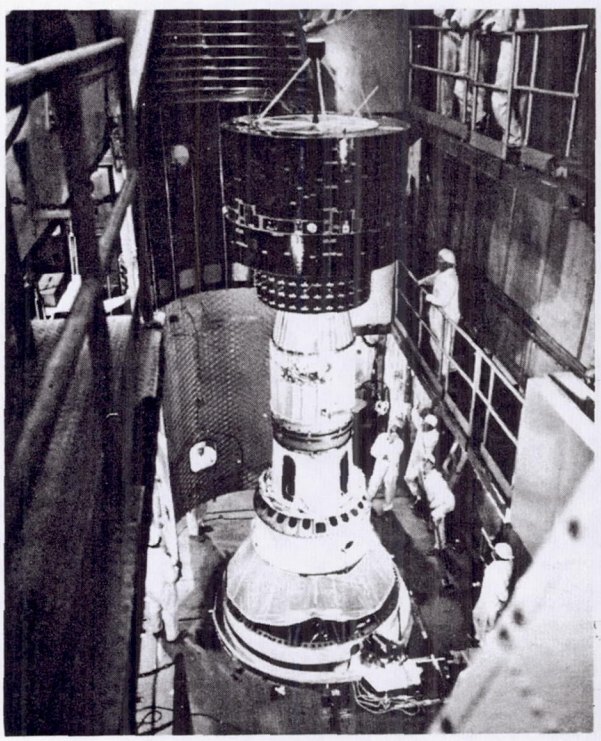
Project Results – GOES-C was launched from Cape Canaveral, Florida, on June 16, 1978 and transferred into a geosynchronous, near-equatorial orbit with an inclination of 0.7 degrees, apogee of 35,804 km and a perigee of 35,709 km.

Major Participants – GOES-C spacecraft prime contractor was Ford Aerospace Corporation. Launch vehicle was constructed by McDonnell-Douglas Astronautics Company, Huntington Beach, California. NASA's Goddard Space Flight Center, Greenbelt, Maryland, procured the spacecraft and launched it, after which it was turned over to NOAA for operational use.

Key Spacecraft Personnel		Affiliation
PM	R. H. Pickard	NASA-GSFC
PS	W. E. Shenk	NASA-GSFC
MG	A. J. Cervenka	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Spin-Scan Radiometer-VISSR	PI	Ness Staff	NOAA-NESS
	OI	W. E. Shenk	NASA-GSFC
Solar Energetic Particles	PI	D. J. Williams	NOAA-ERL
	OI	H. H. Sauer	NOAA-ERL
Solar X-Ray Monitor	PI	D. J. Williams	NOAA-ERL
	OI	R. F. Donnelly	NOAA-ERL
Biaxial Fluxgate Magnetometer	PI	D. J. Williams	NOAA-ERL
	OI	J. N. Barfield	NOAA-ERL
Meteorological Data Collection System	PI	Ness Staff	NOAA-NESS

GOES-C was launched by NASA for the National Oceanic and Atmospheric Administration. This spacecraft was a key element in the Global Weather Experiment, a year-long world-wide weather study.



1978

SEASAT-A

Launch Vehicle – Atlas-Agena. The launch vehicle system consisted of a modified Atlas-F booster, an interstage adapter, a modified fairing, and the Agena bus. The launch vehicle system was 34.6 m long and 3.05 m in diameter. The first stage Atlas provided the initial boost and guidance, and the Agena bus portion of the satellite system provided the injection stage propulsion and guidance functions.

Spacecraft Description – An Agena, second stage of the Atlas/Agena launch vehicle, served as the satellite bus and provided attitude control, power, guidance, telemetry, and command functions. Attached to the Agena was a sensor module which carried the payload of five microwave instruments and their antennas. Together, the two modules were about 21 meters long with a maximum diameter of 1.5 m without appendages deployed. After burnout of the Agena stage and injection into orbit, Seasat-A weighed 2,300 kg. In orbit the satellite appeared to stand on end with the sensor and communications antennas pointing toward Earth and the Agena rocket nozzle and solar panels pointing toward space. Seasat-A was stabilized on its three axes by a momentum wheel/horizon sensing system.

Project Objectives – Seasat-A was designed to demonstrate techniques for global monitoring of oceanographic phenomena and features, to provide oceanographic data, and to determine key features of an operational ocean-dynamics monitoring system. The major difference between Seasat-A and previous Earth observation satellites was the use of active and passive microwave sensors to achieve an all-weather capability.

Spacecraft Payload – The instrument payload included four microwave sensors plus a visual and infrared radiometer. The four microwave sensors consisting of a radar altimeter measured wave height over a range of 2 to 20 m; a scanning multichannel microwave radiometer that measured surface temperature, wind speeds, and provided atmospheric correction data; a microwave scatterometer measured wind speed and direction; and a synthetic aperture radar produced images with a resolution of 25 meters over a swath 100 km wide. The visual and infrared radiometer provided supporting data for the four microwave experiments.

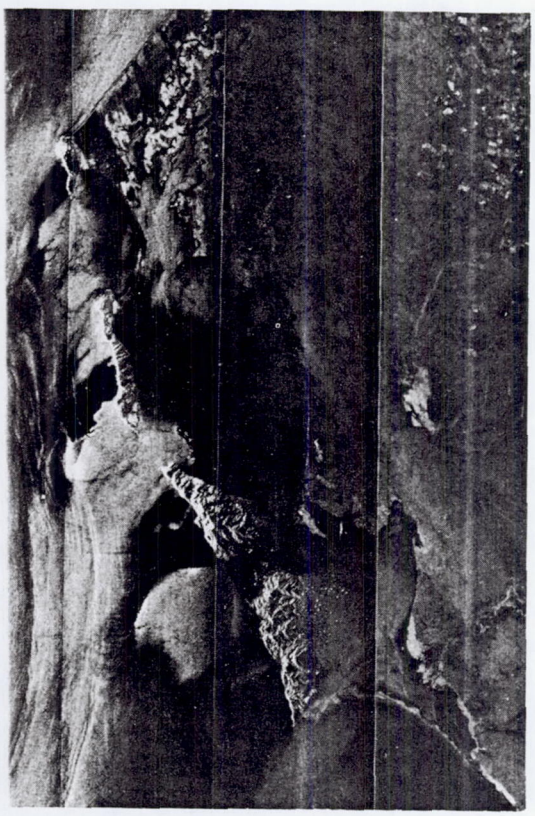
Project Results – Seasat-A was launched from Vandenberg AFB, California, on June 26, 1978. It was injected into a near-circular polar orbit with an apogee of 798 km and a perigee of 775 km. After 106 days of returning data, contact was lost with the satellite on its 1,502nd orbit when a short circuit drained all power from its batteries.

Major Participants – The Seasat program was managed for NASA by the Office of Space and Terrestrial Applications. NASA's Jet Propulsion Laboratory in Pasadena, California, managed the project and the satellite system. Lockheed Missiles and Space Company, Sunnyvale, California, was prime contractor for the satellite system. NASA's Lewis Research Center, Cleveland, Ohio had management responsibility for the launch vehicle.

Key Spacecraft Personnel		Affiliation
MG	S. W. McCandless, Jr.	NASA Headquarters
PM	W. E. Giberson	NASA-JPL
PS	J. A. Dunne	NASA-JPL

Experiment	Experiment Personnel		Affiliation
Compress Pulse Radar Altimeters	CO	J. A. Dunne	NASA-JPL
	TM	S. L. Smith, III	U.S. Naval Surface Weapons Center
	TM	B. H. Chovitz	NOAA-NOS
	TM	W. F. Townsend	NASA-WFC
	TM	J. T. McGoogan	NASA-WFC
	TM	H. M. Byrne	NOAA-PMEL
	TM	E. M. Gaposchkin	SAO
	TM	P. Deleonibus	U.S. Naval Research Laboratory
	TM	B. Yaplee	U.S. Naval Research Laboratory
	TM	C. J. Cohen	U.S. Naval Surface Weapons Center
	TL	B. D. Tapley	University of Texas, Austin
Imaging Radar	CO	J. A. Dunne	NASA-JPL
	TL	P. G. Teleki	U.S. Geological Survey
	TM	D. B. Ross	NOAA-ERL
	TM	W. J. Campbell	U.S. Geological Survey
	TM	A. Loomis	NASA-JPL
	TM	W. E. Brown, Jr.	NASA-JPL
	TM	F. T. Barath	NASA-JPL
	TM	D. H. Rodgers	NASA-JPL
	TM	C. L. Rufenach	NOAA-ERL
	TM	J. W. Sherman, III	NOAA-NESS
	TM	R. Stewart	Scripps Institution of Oceanography
	TM	J. Zelenka	Environmental Research Institute of Michigan
	TM	O. H. Shemdin	NASA-JPL
MW Wind Scatterometer	CO	J. A. Dunne	NASA-JPL
	TL	W. J. Pierson	CUNY Institute Marine and Atmospheric Science
	TM	W. L. Grantham	NASA-LARC
	TM	G. Flittner	NOAA-NWS
	TM	L. Baer	Oceanographic and Atmospheric Service

Experiment	Experiment Personnel		Affiliation
	TM	I. M. Halberstam	NASA-JPL
	TM	W. L. Jones, Jr.	NASA-LARC
	TM	D. Moore	University of Kansas
Scan Vis/Infrared Radiometer	CO	J. A. Dunne	NASA-JPL
	TL	E. P. Mclain	NOAA-NESS
	TM	R. Bernstein	Scripps Institution of Oceanography
	TM	O. K. Huh	Louisiana State University
	TM	W. L. Barnes	NASA-GSFC
	TM	F. M. Vukovich	Research Triangle Institute
	TM	K. D. Fellerman	NASA-GSFC
Scan Multi/MW Radiometer	TL	D. B. Ross	NOAA-ERL
	TM	J. W. Sherman, III	NOAA-NESS
	TM	F. T. Barath	NASA-JPL
	TM	J. Waters	NASA-JPL
	TM	J. P. Hollinger	U.S. Naval Research Laboratory
	TM	T. T. Wilheit, Jr.	NASA-GSFC
	TM	N. Huang	NASA-WFC
	TM	C. T. Swift	NASA-LARC
	TM	W. J. Campbell	U.S. Geological Survey
	TM	V. J. Cardone	Ocean Weather Incorporated
	CO	P. Gloersen	NASA-GSFC
Laser Cube System	PI	J. G. Marsh	NASA-GSFC
S-Band Tracking System	PI	I. M. Salzberg	NASA-GSFC



Radar image of the Baja peninsula coast of Mexico obtained by Seasat-A on July 7, 1978.

COMSTAR D-3

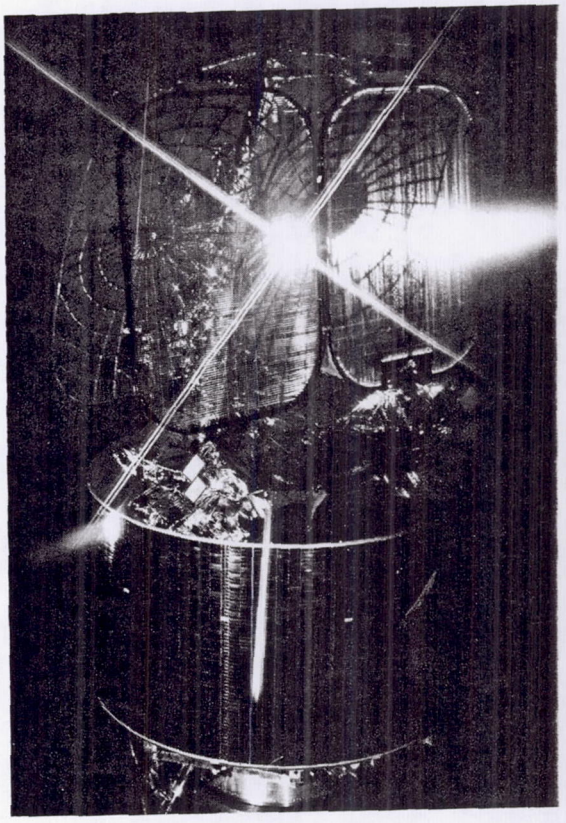
Launch Vehicle – Atlas-Centaur.

Spacecraft Description – COMSTAR D-3 was a cylindrical, spin-stabilized satellite with an overall height of 6 meters and a diameter of 2.4 m. Cylindrical solar panels, covered with nearly 17,000 solar cells provided primary power of 760 watts. Lift-off weight was 1,516 kg, and an in-orbit weight of 792 kg. It had a design life of seven years.

Project Objectives – COMSTAR D-3 was the third high-capacity communications satellite launched for Comsat General Corporation. Capable of relaying more than 18,000 two-way telephone calls simultaneously, it was designed to provide reliable communications service for the continental U.S., Alaska, Hawaii, and Puerto Rico. It served as an operational satellite as well as a backup against failure of one of the other two COMSTAR satellites launched earlier. Its primary mission was to provide domestic communications satellite capabilities for long distance telephone service.

Spacecraft Payload – Each COMSTAR satellite had 24 transponders, each transponder capable of receiving 1,200 one-way calls and relaying them back to Earth on another frequency. Receive frequency band was 5.9 to 6.4 GHz, and transmit frequency band: 3.7 to 4.2 GHz. To conserve frequencies, 12 of the transponders received and transmitted horizontally polarized signals, and 12 handled vertically polarized signals. This signal polarization technique allowed each frequency to be used twice without mutual interference, thus doubling the capacity of the satellite system. In addition, the COMSTAR satellite carried a millimeter wave experimental package to conduct communications tests in the 19 and 29 GHz bands for possible use in future satellite systems.

Project Results – COMSTAR D-3 was launched from Cape Canaveral, Florida, on June 29, 1978. It was in a geosynchronous orbit of 35,852 km over the Equator with an inclination of 0 degrees.



COMSTAR D-3, a high capacity U.S. domestic communications satellite was launched by NASA for the Comsat Corp.

Major Participants — COMSTAR D-3 was designed and built by Hughes Aircraft Company, El Segundo, California. The satellite was launched by NASA under a contract with Comsat General Corporation. It was owned by Comsat General, a subsidiary of the Communications Satellite Corporation. The communications channels were leased to AT&T and GTE Satellite Corporation, a subsidiary of General Telephone Company. AT&T and GTE operated seven earth stations located near San Francisco, Chicago, Atlanta, Scranton, Los Angeles, Tampa, and Honolulu; Lewis Research Center, launch vehicle management; General Dynamics Corp., launch vehicle prime contractor.

GOES-B

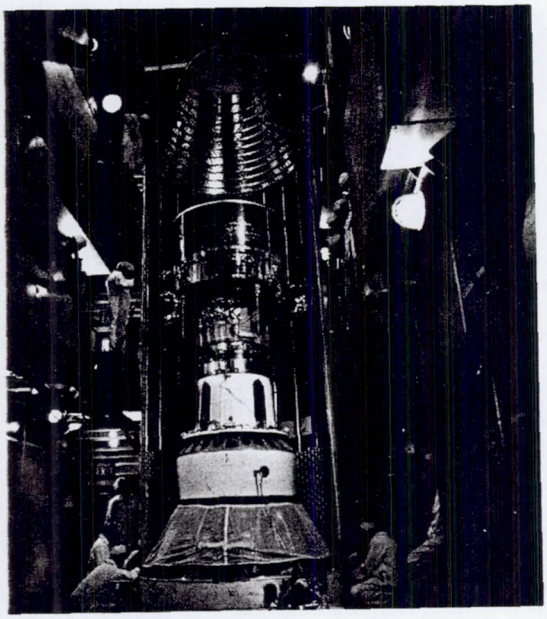
Launch Vehicle – Delta 2914. Three-stage, 35.4 m high/including shroud and with a maximum diameter of 2.4 m without attached strap-on solid propellant rockets. Lift-off weight was 131,895 kg and lift-off thrust, including nine solid-propellant Thiokol rockets was 1,765,315 Newtons.

Spacecraft Description – The cylindrically-shaped satellite weighing 575 kg at lift-off, including seven experiments, and apogee kick motor. Antenna and experiment booms and appendages were extended from the top and bottom sections of the satellite.

Project Objectives – The mission of GEOS-B was to study the magnetosphere in the region of its orbit. It was to be positioned on those magnetic field lines that are linked to Earth's auroral zones, and the data it acquired was to be correlated with similar data from auroral stations served by ground-based, balloon-borne, or rocket-borne instruments.

Spacecraft Payload – Except for minor modifications to certain spacecraft subsystems, the seven GEOS-B experiments were the same as for GEOS-A. They were provided by 11 research institutes in eight ESA member countries (Denmark, France, Germany, Italy, Netherlands, Sweden, Switzerland, and the United Kingdom).

Project Results – GEOS-B was launched from Cape Canaveral, Florida, on July 14, 1978, and was placed in a geosynchronous orbit of 35,542 km with an inclination of 0.5 degrees. The satellite's position above the Equator was shifted between 9 degrees and 35 degrees E longitude during the first year of operation to correlate satellite data with ground station, balloon, and sounding rocket measurements made on the same magnetic longitude.



Major Participants – GEOS-B was designed and constructed by the European STAR Consortium of companies under contract to the European Space Agency (ESA). British Aerospace Dynamics Group was prime contractor responsible for project management. Other STAR Consortium team members constructed and integrated the experiments and satellite components. Prime contractor for the Delta launch vehicle was McDonnell Douglas Astronautics Company of Huntington Beach, California. NASA-Goddard Space Flight Center managed the Delta program.

Technicians are preparing the European Space Agency's GOES-B satellite for launch from Cape Canaveral, Florida. Launched on a Delta vehicle, the satellite was to be placed in a stationary orbit 22,300 miles above the equator in Africa to study the Earth's magnetosphere.

PIONEER VENUS-B (Multiprobe)

Launch Vehicle – Atlas-Centaur.

Spacecraft Description – Pioneer Venus-B, a multiprobe, was made up of a transporter bus, a large probe, and three identical smaller probes. All were to enter the atmosphere of Venus at various points, and all carried instruments and sensors to measure atmospheric and surface phenomena. The transponder was a spin-stabilized, short cylinder 2.4 m in diameter housing instruments, communications, and navigation systems. All four probes were geometrically similar. The main component of each housed instruments, communications, data, command, and power systems. The large probe weighed 316 kg, was 1.5 m in diameter; its seven instruments weighed 28 kg. The smaller north, day, and night probes (named for their destination on the planet's surface) each weighed 93 kg. The four probes were launched from the multiprobe 13 million km from the planet to fly to their entry points, two on the day side and two on the night side of Venus. The probe pressure vessels were made of titanium for pressure and heat resistance. Windows for infrared radiometer instruments consisted of diamonds (13.5 carats on the large probe, cut from a 205-carat industrial grade rough diamond). The multiprobe spacecraft weighed 904 kg and carried 51 kg of scientific instruments.

Project Objectives – The multiprobe divided into five atmosphere entry craft as it approached Venus from Earth: the transporter unit (bus), the large probe and three small probes. The probes measured Venusian atmosphere from its uppermost levels down to the superheated regions at the surface. After launching the probes, the bus, too, entered and measured the composition of Venus' upper atmosphere before burning up. The objectives of these probes was to determine the atmospheric structure of Venus from 200 km to impact at four entry sites well separated from one another. Temperature, pressure, and acceleration sensors on all four probes were designed to yield data on the location and intensities of atmospheric turbulence, the variation of temperatures with pressure and altitude, the average atmospheric molecular weight, and the radial distance to the center of Venus.

Spacecraft Payload – The large probe weighed about 316 kg and was about 1.5 m in diameter. It contained seven scientific instruments: a neutral mass spectrometer, a gas chromatograph, a solar flux radiometer, an infrared radiometer, a cloud particle size spectrometer, a nephelometer, and pressure/temperature/acceleration sensors. The three small probes were identical, 0.8 m in diameter, weighing 90 kg. Like the large probe, each of the small probes consisted of a forward heat shield, a pressure vessel, and an afterbody. Each carried a nephelometer, a net flux radiometer, and pressure/temperature/acceleration sensors. Each probe also carried a communications system consisting of a solid state transmitter and a hemispherical coverage antenna. All four probes contained a command system, data handling system, and power system. The multiprobe bus carried a neutral mass spectrometer and an ion mass spectrometer which provided the mission's only high upper atmosphere composition measurements, operating as the bus entered the atmosphere but before it started to burn up at 115 km.

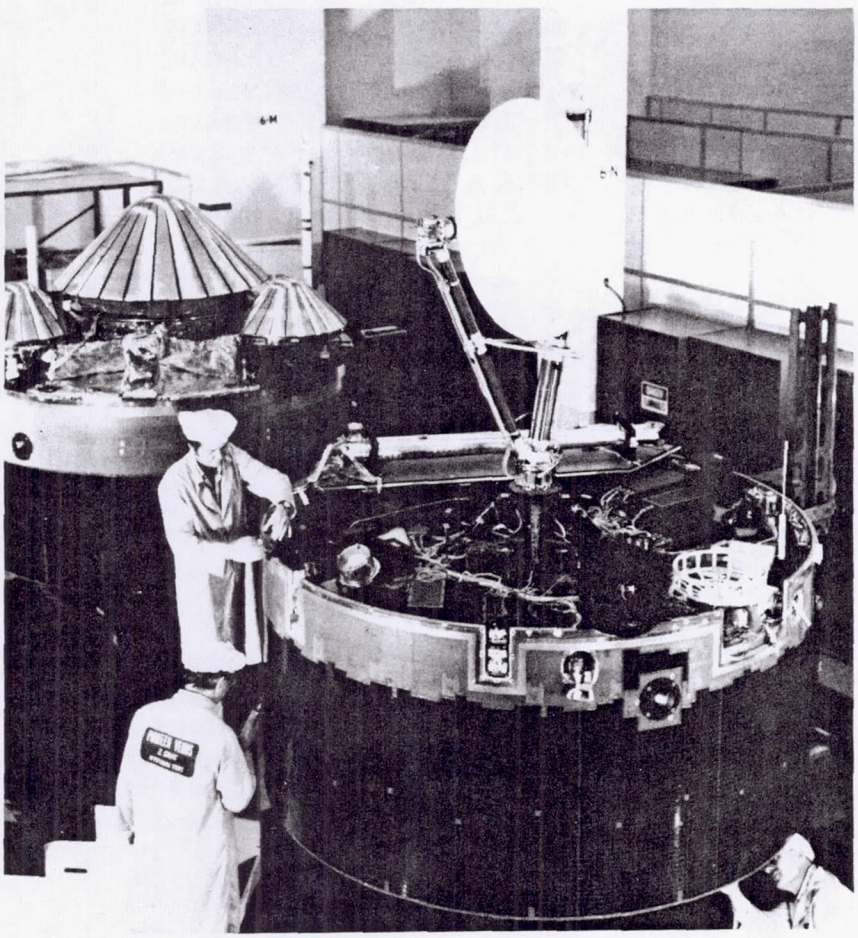
Project Results – Pioneer Venus-B was launched from Cape Canaveral, Florida on August 8, 1978. Between November 15 and 21, when Pioneer Venus-B was still about 7 million miles from the planet, the four probes were launched from the spacecraft. All four probes and the bus transporter entered the Venusian atmosphere on December 9, 1978, and all successfully transmitted scientific data. The large probe, north probe, and night probe went dead upon impact with the surface, but the day probe continued to transmit signals for 68 minutes after impact.

Major Participants - Spacecraft designed and built by Hughes Aircraft Company, El Segundo, California. The Pioneer Venus program was managed by NASA's Ames Research Center, Mountain View, California. NASA's deep space tracking network handled tracking and data transmission; Lewis Research Center, launch vehicle management; General Dynamcis Corp., launch vehicle prime contractor.

Key Spacecraft Personnel		Affiliation
Pioneer Venus Probe Bus	PM C. F. Hall	NASA-ARC
	PS L. Colin	NASA-ARC
	MG F. D. Kochendorfer	NASA Headquarters
	SC R. E. Murphy	NASA Headquarters
Pioneer Venus Probe Lrg.	PM C. F. Hall	NASA-ARC
	PS L. Colin	NASA-ARC
	MG F. D. Kochendorfer	NASA Headquarters
	SC M. A. Mitz	NASA Headquarters
Pioneer Venus Probe SM1	PM C. F. Hall	NASA-ARC
	PS L. Colin	NASA-ARC
	MG F. D. Kochendorfer	NASA Headquarters
	SC M. A. Mitz	NASA Headquarters
Pioneer Venus Probe SM2	PM C. F. Hall	NASA-ARC
	PS L. Colin	NASA-ARC
	MG F. D. Kochendorfer	NASA Headquarters
	SC M. A. Mitz	NASA Headquarters
Pioneer Venus Probe SM3	PM C. F. Hall	NASA-ARC
	PS L. Colin	NASA-ARC
	MG F. D. Kochendorfer	NASA Headquarters
	SC M. A. Mitz	NASA Headquarters

Experiment	Experiment Personnel	Affiliation
Ion-Mass Spectrometer	PI H. A. Taylor, Jr.	NASA-GSFC
	OI S. J. Bauer	NASA-GSFC
	OI T. M. Donahue	University of Michigan
	OI P. A. Cloutier	Rice University
	OI R. E. Hartle	NASA-GSFC
	OI H. C. Brinton	NASA-GSFC
	OI F. C. Michel	Rice University
Neutral Particles Mass Spectrometer	PI U. Von Zahn	University of Bonn
	OI A. O. C. Nier	University of Minnesota
	OI D. M. Hunten	University of Arizona

Experiment	Experiment Personnel		Affiliation
Atmosphere Circulation Patterns	PI	C. C. Counselman	Massachusetts Institute of Technology
	OI	I. I. Shapiro	Massachusetts Institute of Technology
	OI	R. G. Prinn	Massachusetts Institute of Technology
	OI	J. Charney	Massachusetts Institute of Technology
	OI	G. Pettengill	Massachusetts Institute of Technology
Radio Science Team	TL	G. Pettengill	Massachusetts Institute of Technology
	TM	T. A. Croft	SRI International
	TM	A. J. Kliore	NASA-JPL
	TM	R. Woo	NASA-JPL
Participating Theorist	PI	S. J. Bauer	NASA-GSFC
Participating Theorist	PI	T. M. Donahue	University of Michigan
Participating Theorist	PI	R. M. Goody	Harvard University



Technicians at Ames Research Center work on Venus orbiter, and multi-probe spacecraft.

Experiment	Experiment Personnel		Affiliation
Participating Theorist	PI	D. M. Hunten	University of Arizona
Participating Theorist	PI	J. B. Pollack	NASA-ARC
Participating Theorist	PI	N. W. Spencer	NASA-GSFC
Atmospheric Structure	PI	A. Seiff	NASA-ARC
	OI	S. C. Sommer	NASA-ARC
	OI	R. C. Blanchard	NASA-LARC
	OI	D. B. Kirk	NASA-ARC
	OI	R. E. Young	NASA-ARC
	OI	J. Derr	U.S. Geological Survey
Cloud Extend. Structure Distribution	OP	J. E. Blamont	CNRS-SA
	PI	B. Ragent	NASA-ARC
Cloud Particle Size Spectrometer	PI	R. Knollenberg	University of Chicago
	OI	D. M. Hunten	University of Arizona
Gas Chromatograph	PI	V. I. Dyama	NASA-ARC
	OI	J. B. Pollack	NASA-ARC
	OI	G. Carle	NASA-ARC
	OI	F. Woeller	NASA-ARC
Iridium Radiometer	PI	R. W. Boese	NASA-ARC
	OI	J. B. Pollack	NASA-ARC
	OI	J. H. Miller	NASA-ARC
	OI	L. P. Giver	NASA-ARC
Neutral Particles Mass Spectrometer	PI	J. H. Hoffman	University of Texas, Dallas
	OI	R. R. Hodges, Jr.	University of Texas, Dallas
	OI	M. Kolpin	TRW Systems Group
	OI	M. B. McElroy	Harvard University
	OI	T. M. Donahue	University of Michigan
Solar Energy Penetration	PI	M. G. Tomasko	University of Arizona
	OI	W. Wolff	University of Arizona
	OI	A. Clements	University of Arizona
Atmosphere Circulation Patterns	PI	C. C. Counselman	Massachusetts Institute of Technology
	OI	G. Pettengill	Massachusetts Institute of Technology
	OI	I. I. Shapiro	Massachusetts Institute of Technology
	OI	R. G. Prinn	Massachusetts Institute of Technology
	OI	J. Charney	Massachusetts Institute of Technology

Experiment	Experiment Personnel		Affiliation
Atmospheric Structure Multiple Experiments	PI	A. Seiff	NASA-ARC
	OI	S. C. Sommer	NASA-ARC
	OI	D. B. Kirk	NASA-ARC
	OI	R. C. Blanchard	NASA-LARC
	OI	R. E. Young	NASA-ARC
	OI	J. Derr	U.S. Geological Survey
Cloud Extent, Structure, Distribution, Multiple Experiments	OP	J. E. Blamont	CNRS-SA
	PI	B. Ragent	NASA-ARC
Atmosphere Circulation Patterns Multiple Experiments	PI	C. C. Counselman	Massachusetts Institute of Technology
	OI	I. I. Shapiro	Massachusetts Institute of Technology
	OI	R. G. Prinn	Massachusetts Institute of Technology
	OI	S. Charney	Massachusetts Institute of Technology
	OI	G. Pettengill	Massachusetts Institute of Technology
Infrared Radiometer	PI	V. E. Suomi	University of Wisconsin
	OI	J. Lenoble	University of Lille
Multiple Experiments	OI	L. A. Sromovsky	University of Wisconsin
	OI	A. Fymat	NASA-JPL
	OI	G. E. Danielson	NASA-JPL
	OI	M. Herman	University of Lille
Atmospheric Structure	PI	A. Seiff	NASA-ARC
	OI	S. C. Sommer	NASA-ARC
	OI	D. B. Kirk	NASA-ARC
	OI	R. C. Blanchard	NASA-LARC
	OI	R. E. Young	NASA-ARC
	OI	J. Derr	U.S. Geological Survey
Ion Mass Spectrometer	PI	H. A. Taylor, Jr.	NASA-GSFC
	OI	S. J. Bauer	NASA-GSFC
	OI	T. M. Donahue	University of Michigan
	OI	P. A. Cloutier	Rice University
	OI	R. E. Hartle	NASA-GSFC
	OI	H. C. Brinton	NASA-GSFC
	OI	F. C. Michel	Rice University
Neutral Particle Mass Spectrometer	PI	U. Von Zahn	University of Bonn
	OI	A. O. C. Nier	University of Minnesota
	OI	D. M. Hunten	University of Arizona

INTERNATIONAL SUN-EARTH EXPLORER C (ISEE C)

Launch Vehicle – Delta 144.

Spacecraft Description – ISEE-C was a 16-sided polyhedron approximately 1.73 meters across and 1.61 meters high. The main body consisted of an 84 cm conical center tube. ISEE-C weighed 469 kg. Solar cells, mounted on the sides of the spacecraft provided power for the experiments and transmission.

Project Objectives – ISEE-C monitored the characteristics of solar phenomena about one hour before ISEE-A and ISEE-B which were in elliptical, near-Earth orbits, and which measured the same phenomena. The correlated measurements enabled 117 scientific investigators representing 35 universities in 10 nations to gain a better understanding of how the Sun controls the Earth's near space environment.

Spacecraft Payload – ISEE-C weighed 479 kg.

Project Results – ISEE-C was launched from Cape Canaveral, Florida on August 12, 1978 and moved into orbit around libration point L-1 in November 1978. Its halo orbit was about 1.5 km (932,000 miles) from Earth.

Major Participants - ISEE-C was designed and constructed by NASA at Goddard Space Flight Center. McDonnell Douglas, Huntington Beach, California, was the prime contractor for the Delta launch vehicle; Lewis Research Center, launch vehicle management; General Dynamcis Corp., launch vehicle prime contractor.

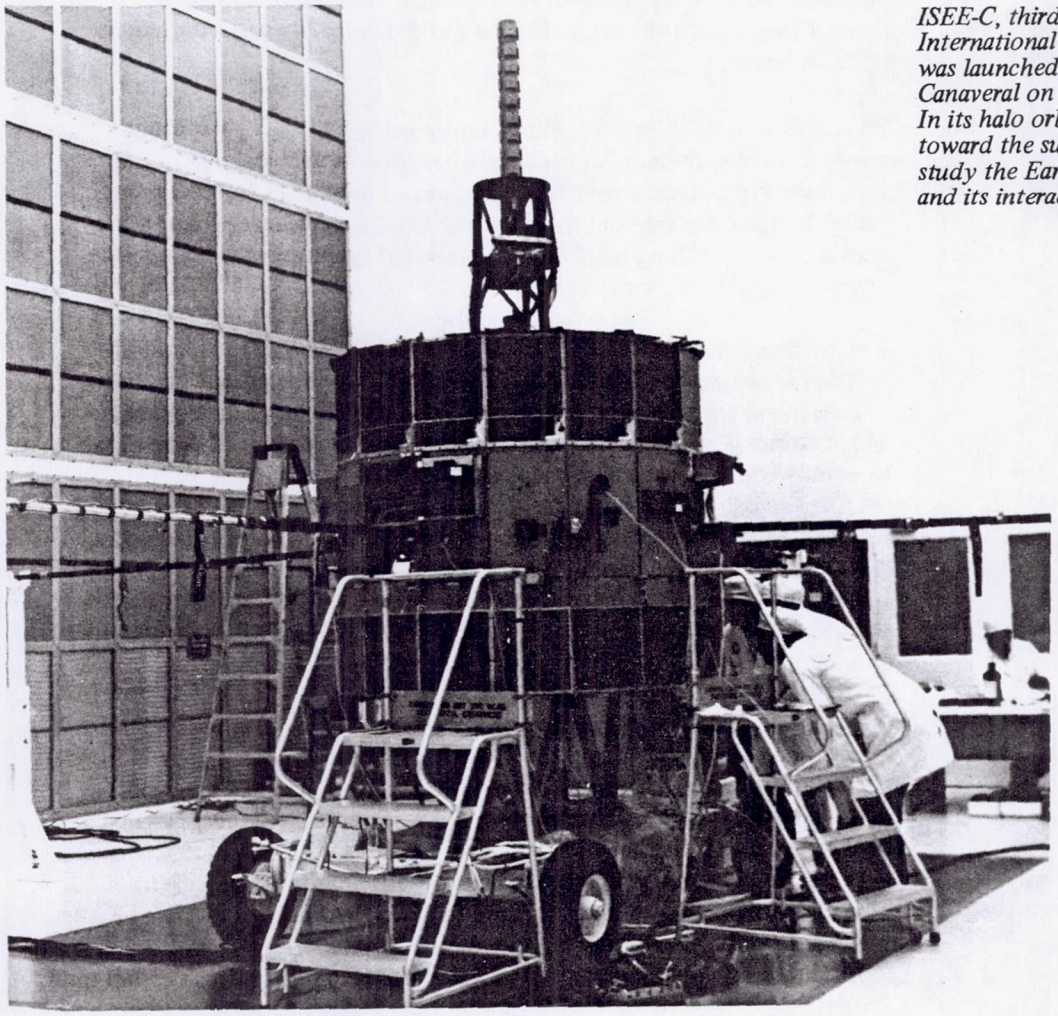
Key Spacecraft Personnel		Affiliation
MG	J. P. Corrigan	NASA-GSFC
PM	R. O. Wales	NASA-GSFC
SC	M. J. Aucremanne	NASA Headquarters
PS	T. T. Von Rosenvinge	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Solar Wind Plasma	PI	S. J. Bame	Los Alamos Science Laboratory
	OI	J. R. Asbridge	Los Alamos Science Laboratory
	OI	E. W. Hones, Jr.	Los Alamos Science Laboratory
	OI	M. D. Montgomery	Los Alamos Science Laboratory
	OI	W. C. Feldman	Los Alamos Science Laboratory
Magnetic Fields	PI	E. J. Smith	NASA-JPL
	OI	L. Davis, Jr.	California Institute of Technology
	OI	G. L. Siscoe	University of California, Los Angeles

Experiment	Experiment Personnel		Affiliation
	OI	D. E. Jones	Brigham Young University
	OI	B. T. Tsurutani	NASA-JPL
Low-Energy Cosmic Rays	OI	J. J. O'Gallagher	University of Maryland
	OI	C. Y. Fan	University of Arizona
	OI	G. Gloeckler	University of Maryland
	PI	D. K. Hovestadt	MPI-Extraterrestrial Physics
	OI	M. Scholer	MPI-Extraterrestrial Physics
	OI	L. A. Fisk	University of New Hampshire
Medium Energy Cosmic Rays	PI	T. T. Von Rosenvinge	NASA-GSFC
	OI	L. A. Fisk	University of New Hampshire
	OI	F. B. McDonald	NASA-GSFC
	OI	J. H. Trainor	NASA-GSFC
	OI	M. A. Van Hollebeke	University of Maryland
High Energy Cosmic Rays	PI	H. H. Heckman	Lawrence Berkeley Laboratory
	OI	D. E. Greiner	University of California, Berkeley
Cosmic Ray Electrons, Nuclei	PI	P. Meyer	University of Chicago
	OI	P. Evenson	University of Chicago
Plasma Waves	PI	F. L. Scarf	TRW Systems Group
	OI	D. A. Gurnett	University of Iowa
	OI	E. J. Smith	NASA-JPL
	OI	R. W. Fredericks	TRW Systems Group
Energetic Protons	OI	J. J. Van Rooijen	University of Utrecht
	OI	J. N. Van Gils	University of Utrecht
	OI	R. M. Van Den Nieuwenhof	University of Utrecht
	OI	K. P. Wenzel	ESA-ESTEC
	OI	A. C. Durney	ESA-ESTEC
	OI	T. R. Sanderson	ESA-ESTEC
	PI	R. J. Hynds	Imperial College
	OI	V. Domingo	ESA-ESTEC

Experiment	Experiment Personnel		Affiliation
	OI	D. E. Page	ESA-ESTEC
	OI	A. Balogh	Imperial College
	OI	C. De Jager	University of Utrecht
	OI	H. Elliot	Imperial College
Interplanetary and Solar Electrons	PI	K. A. Anderson	University of California, Berkeley
	OI	R. P. Lin	University of California, Berkeley
	OI	D. F. Smith	High Altitude Observatory
	OI	S. R. Kane	University of California, Berkeley
Radio Mapping	PI	J. L. Steinberg	Paris Observatory
	OI	P. Couturier	Paris Observatory
	OI	R. Knoll	Paris Observatory
	OI	J. Fainberg	NASA-GSFC
	OI	R. G. Stone	NASA-GSFC
	OI	S. R. Mosier	National Science Foundation
Solar Wind Ion Composition	PI	K. W. Ogilvie	NASA-GSFC
	OI	J. Geiss	University of Berne
	OI	M. H. Acuna	NASA-GSFC
	OI	M. A. Coplan	University of Maryland
	OI	D. L. Lind	NASA-JSC
High-Energy Cosmic Rays	PI	E. C. Stone	California Institute of Technology
	OI	R. E. Vogt	California Institute of Technology
Ground Based Solar Studies	PI	J. M. Wilcox	Stanford University
X- and Gamma-Ray Bursts	PI	K. A. Anderson	University of California, Berkeley
	OI	S. R. Kane	University of California, Berkeley
	OI	W. D. Evans	Los Alamos Science Laboratory
	OI	R. W. Klebesadel	Los Alamos Science Laboratory

Experiment		Experiment Personnel	Affiliation
Gamma-Ray Bursts	OI	D. K. Hovestadt	MPI-Extraterrestrial Physics
	PI	B. J. Teegarden	NASA-GSFC
	OI	T. L. Cline	NASA-GSFC
	OI	G. Gloeckler	University of Maryland



ISEE-C, third in a series of International Sun Earth Explorers, was launched successfully at Cape Canaveral on August 12, 1978. In its halo orbit 900,000 miles toward the sun, ISEE-C was to study the Earth's magnetosphere and its interactions with the Sun.

TIROS-N

Launch Vehicle – Atlas-E/F; the second stage consisted of a TE-364-15 solid motor which was used as an injection motor. Overall length including fairing was 293 m and maximum body diameter was 3 meters.

Spacecraft Description – The spacecraft, including the apogee kick motor in the launch configuration, was 371 cm high and 188 cm in diameter and weighed nominally 1,405 kg. In orbit, with the apogee kick motor and reaction-control equipment expendables consumed, the satellite had a nominal weight of 723 kg.

The spacecraft 'bus' consisted of the following subsystems: structure-thermal, power, attitude determination and control and communications and data handling.

Project Objectives – First of eight in a third generation of polar orbiting environmental spacecraft, which carried new environmental monitoring instruments into space providing significant technological advances over earlier National Oceanic and Atmospheric Administration (NOAA) spacecraft which it was to replace. Once in orbit, NOAA operated the satellite and processed the data it received.

For the first time, because of its advanced data collection and platform location system, the Tiros-N spacecraft provided an operational capability to collect and transmit environmental data from platforms on land, at sea, and airborne, and also determined the geographic locations of those platforms when they were in motion on the sea or land surface or aloft.

Satellite data provided more precise evaluation of land, ice, surface water, cloud conditions, and sea surface temperatures, while also transmitting in real time to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users located in more than 100 countries around the world.

Specific objectives included improved methods of obtaining quantitative environmental data and improved data handling capabilities through: higher resolution, day and night cloud cover observations on a local and global scale; high resolution observations of sea surface temperatures; improved observations of vertical temperature and water vapor profiles in the troposphere and lower stratosphere on a global basis; observations of vertical temperature profiles in the middle and upper stratosphere on a global basis; operational flight of a high-capacity data collection/relay and platform location system; and observations of electron and proton flux densities and total particle energy densities in the near-Earth space environment.

The sensors were multi-national in character: a stratospheric sounding unit from Great Britain and a data collection and platform location system from France, while the other sensors were developed in the United States.

The Tiros-N system was to serve as a primary source of data for the First Global Atmospheric Research Program, Global Experiment, an international cooperative project involving some 140 countries, which started on Decem-

ber 1, 1978. Its instrumentation payload was designed to meet FGGE requirements for quantitative data of the Earth's atmosphere and sea surface essential to the solution of atmospheric numerical models for improved long-range weather forecasts.

Spacecraft Payload – Tiros-N instrumentation included an Advanced Very High Resolution Radiometer (AVHRR) to provide timely data on day and night sea surface temperatures, ice, snow, and cloud conditions.

The satellite also carried a data collection and platform location subsystem which could receive, process, and store data from fixed and moving platforms, including free-floating balloons and buoys, for transmission to a central processing facility.

An atmospheric sounding system provided a vertical temperature profile of the atmosphere from the Earth's surface to near the top of the atmosphere (1 mb) and a moisture vapor content profile from the surface to the tropopause. A space environment monitor provided for continuous measurements of the proton alpha and electron flux activity near Earth. This instrument was an extension of the solar portion monitor package aboard the earlier ITOS satellites. Sounder system data along with radiometry data were telemetered through the Tiros-N information processor telemetry system.

Project Results – Tiros-N was launched from the Western Test Range on October 13, 1978; its orbital elements were 865 km apogee and 850 km perigee, inclination 98.9°, period: 102 minutes.

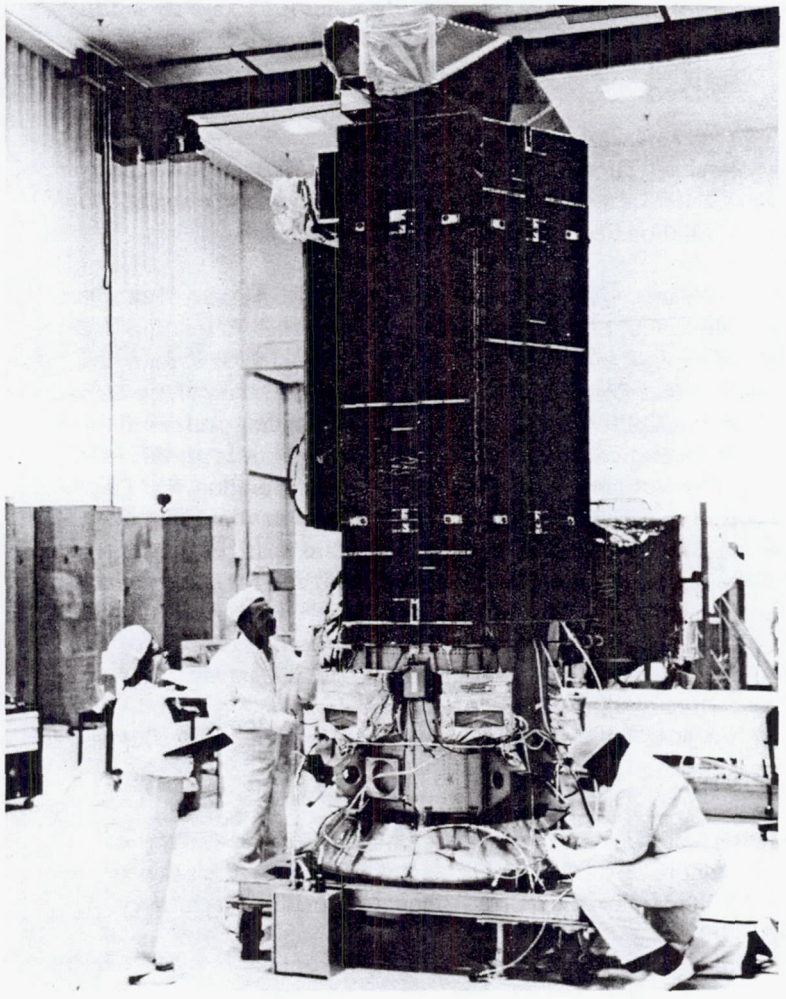
Major Participants – The spacecraft was built by RCA Astro Electronics Division, Princeton, New Jersey; Advanced Very High Resolution Radiometer, High Resolution Infrared Radiometer Sounder/2 was built by ITT-Aerospace/Optical Division, Fort Wayne, Indiana; Jet Propulsion Laboratory, Pasadena, California built the microwave sounding unit; Ford Aerospace Communications Corporation, Palo Alto, California provided the space environment monitor; General Dynamics Corporation, San Diego, California Atlas-E/F launch vehicle; Thiokol Corporation, Huntsville, Alabama the apogee kick motor. NASA Goddard Space Flight Center had overall responsibility for spacecraft development and for launch vehicle system. Ground communication links for Tiros-N were provided by RCA Satcom and Goddard's NASA communications network. After launch NOAA's command and data acquisition stations handled all data transmissions. Primary stations were located at Fairbanks, Alaska and Wallops Station, Virginia. Limited facilities were also provided by a facility at Lannion, France.

International participants included the United Kingdom, Ministry of Defense Meteorological Office (British Met Office); France's Centre National d'Etudes Spatiales (CNES); and the Canadian Department of Communications, Communications Research Center (CRC), in the later phases of the series.

Key Spacecraft Personnel		Affiliation
MG	A. J. Cervenka	NASA Headquarters
PM	J. Fuller, Jr.	NASA-GSFC
PS	A. Arking	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Advanced Very High Resolution Radiometers	PI	Ness Staff	NOAA-NESS
	CO	W. F. Shenk	NASA-GSFC
Operational Vertical Sounder	PI	Ness Staff	NOAA-NESS
Data Collection System	PI	Ness Staff	NOAA-NESS
Space Environment Monitor	PI	D. J. Williams	NOAA-ERL
	OI	C. O. Bostrom	Applied Physics Laboratory
	OI	H. H. Sauer	NOAA-ERL

TIROS-N being tested at RCA Space Center, Princeton, N.J., prior to launch on October 13, 1978.



NIMBUS-G and PROJECT CAMEO

Launch Vehicle – Delta 2910. Two-stage, 35.3 meter tall launch vehicle consisted of a liquid-fuel Thor booster with nine Thiokol strap-on Castor II solid-fuel rocket motors, and a TRW liquid-fuel second stage engine. Lift-off weight of the launch vehicle was 132,180 kg.

Spacecraft Description – Similar to the previous six spacecraft in this series, in its orbit configuration with solar arrays deployed, it was a butterfly-shaped satellite measuring about 3 meters high and approximately 2 m wide. Orbital weight was 987 kg and its three-axis attitude control subsystem kept its sensors pointed toward Earth with an accuracy of better than 1 degree about all axes. Spacecraft and experiment data were transmitted to Earth stations immediately, or stored in an on-board high-speed tape recorder for subsequent playback when the satellite was in view of a ground acquisition station.

Project Objectives – Nimbus-G was the first satellite to provide continuous, worldwide environmental data to help scientists throughout the world determine the physical characterization of the global atmosphere, the oceans, the dynamic atmosphere-ocean interface, and the Earth's heat balance. For the first time, the European Space Agency (ESA) received and processed direct Nimbus-G data at Lannion, France.

Spacecraft Payload – The spacecraft carried eight highly complex sensors – seven from the U.S. and one from Great Britain – which were improved versions of one or more instruments flown on the six previous Nimbus satellites. These instruments were: a limb scanning infrared radiometer, a stratospheric and mesospheric sounder, a stratospheric aerosol measurement device, a solar and back-scattered UV/total ozone mapping system, an Earth radiation budget system, a scanning multichannel microwave radiometer, a coastal zone color scanner, and a temperature/humidity infrared radiometer. After separation from Nimbus-G, the Delta launch vehicle released lithium over northern Scandinavia and barium over northern Alaska as a part of Project Cameo (Chemically Active Materials Ejected in Orbit). The project observed solar energy and plasma flows and electric fields in the Arctic.

Project Results – Nimbus-G was launched from Vandenberg AFB, California, on October 24, 1978 in a circular, near-Polar orbit with an inclination of 99.3 degrees and a period of 104 minutes. Apogee was 954 km and perigee was 953 km.

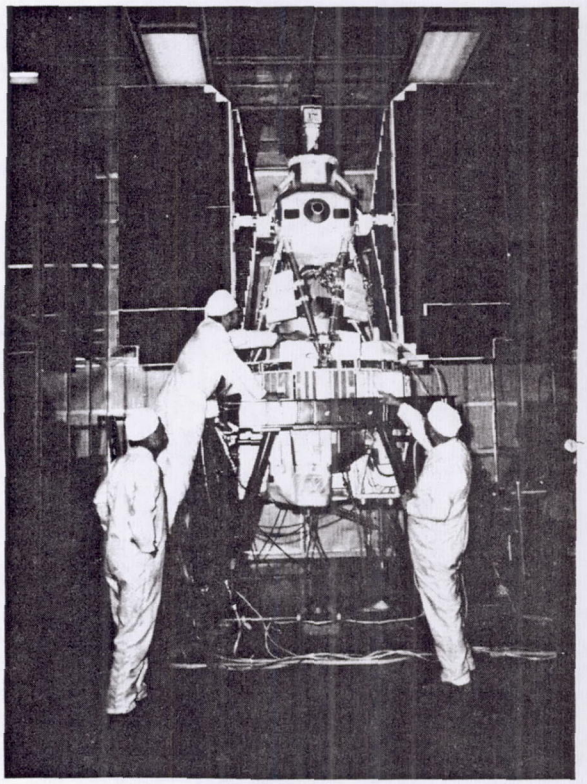
Major Participants – Nimbus-G was constructed by the Space Division of General Electric Company, Valley Forge, Pennsylvania. McDonnell-Douglas Astronautics Company, Huntington Beach, California, was the prime contractor for the Delta launch vehicle. The Nimbus program was directed by NASA's Office of Space and Terrestrial Applications, Washington, D.C. The European Space Agency was responsible for receiving, processing, and distributing Nimbus-G data to European investigators.

Key Spacecraft Personnel		Affiliation
Nimbus-G		
PS	A. J. Fleig	NASA-GSFC
CO	D. M. Streaker	NASA-GSFC
PM	C. M. Mackenzie	NASA-GSFC
SC	R. J. Arnold	NASA Headquarters
CAMEO		
PM	J. P. Heppner	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Nimbus-G			
LIMB Infrared Monitoring of the Stratosphere	TL	J. M. Russell, III	NASA-LARC
	OT	J. C. Gille	National Center for Atmospheric Research
	TM	F. B. House	Drexel Institute of Technology
	TM	E. E. Remsberg	NASA-LARC
	TM	C. B. Loevy	University of Washington
	TM	S. R. Drayson	University of Michigan
	TM	H. Fischer	University of Munich
	TM	W. G. Planet	NOAA-NESS
	TM	A. Girard	Onera
	TM	J. E. Harries	National Physical Laboratory
Stratospheric and Mesospheric Sounder	PI	J. T. Houghton	Oxford University
	OI	G. D. Peskett	Clarendon Laboratory
	OI	C. D. Rodgers	Oxford University
	CO	J. W. Lovelace, Jr.	NASA-GSFC
	OI	E. J. Williamson	Clarendon Laboratory
Coastal Zone Color Scanner	TL	W. A. Hovis	NOAA-NESS
	TM	H. L. Richard	NASA-GSFC
	TM	C. S. Yentsch	Bigelow Laboratory of Ocean Sciences
	TM	D. Clark	NOAA-NESS
	TM	J. R. Apel	NOAA-PMEL
	TM	S. Z. El-Sayed	Texas A&M
	TM	H. R. Gordon	NOAA-PMEL
	TM	R. C. Wrigley	NASA-ARC
	TM	F. P. Anderson	National Research Institute of Oceanology
	TM	R. Austin	Scripps Institution of Oceanography

Experiment	Experiment Personnel		Affiliation
Stratospheric Aerosol Measurement Radiometer	TL	M. P. McCormick	NASA-LARC
	TM	T. J. Pepin	University of Wyoming
	TM	G. W. Grams	National Center for Atmospheric Research
	TM	B. M. Herman	University of Arizona
	TM	P. B. Russell	SRI International
Earth Radiation Budget	TL	H. Jacobowitz	NOAA-NESS
	TM	T. H. Vonderhaar	Colorado State University
	TM	F. B. House	Drexel Institute of Technology
	TM	K. L. Coulson	University of California, Davis
	TM	J. R. Hickey	Eppley Laboratory, Inc.
	TM	L. L. Stowe	NOAA-NESS
	TM	A. P. Ingersoll	California Institute of Technology
	TM	G. L. Smith	NASA-LARC
Scanning Multichannel Microwave Radiometer	TL	P. Gloersen	NASA-GSFC
	TM	R. O. Ramseir	Environment Canada
	TM	D. H. Staelin	Massachusetts Institute of Technology
	TM	W. J. Campbell	U.S. Geological Survey
	TM	D. B. Ross	NOAA-ERL
	TM	P. Gudmansen	Technical University of Denmark
	TM	F. T. Barath	NASA-JPL
	TM	T. T. Wilheit, Jr.	NASA-GSFC
Solar and Backscatter Ultraviolet Spectrometer Total Ozone Mapping System	TL	D. F. Heath	NASA-GSFC
	TM	C. L. Mateer	Environment Canada
	TM	A. D. Belmont	Control Data Corporation
	TM	A. J. Miller	NOAA-NWS
	TM	A. F. S. Green	University of Florida
	TM	D. M. Cunnold	Massachusetts Institute of Technology
	TM	W. L. Imhof	Lockheed Palo Alto
	TM	A. J. Krueger	NASA-GSFC
Temperature Humidity Improved Radiometer	PI	L. J. Allison	NASA-GSFC
	CO	J. W. Lovelace, Jr.	NASA-GSFC
	CO	G. T. Cherrix	NASA-GSFC
CAMEO			
Barium and Lithium Release Modules	PI	J. P. Heppner	NASA-GSFC

Nimbus-G at the Western Test Range in California. Its sensors were to provide continuous environment data on the global atmosphere, the oceans, the dynamic atmosphere/ ocean interface, and the Earth's heat balance.



HEAO-B

Launch Vehicle – Atlas-Centaur. Satellite weight 3,151 kg.

Spacecraft Description – Two main parts, an experiment module and a spacecraft equipment module (SEM). The experiment module was eight-sided, about 254 centimeters wide and 575 centimeters high from its attachment to the SEM to the top of the solar panels. The SEM was an octagon-shaped prism, 83.8 centimeters high and 231 centimeters in diameter. The spacecraft had an overall height of about 6.6 meters; at launch it weighed about 3,146 kilograms.

Project Objectives – Carrying the largest X-ray telescope ever built, HEAO-B was the second in a series of three large observatories designed to study the "high energy universe," i.e., X-rays, gamma rays, and cosmic particles. The scientific objectives of the HEAO program were to learn more about some of the most puzzling objects in the universe: pulsars, neutron stars, black holes, quasars, radio galaxies, and supernovas. Many of these radiate only in the X-ray, gamma ray, and cosmic ray regions of the electromagnetic spectrum and cannot be studied from the ground because of the obscuring effects of the Earth's atmosphere.

Spacecraft Payload – The X-ray telescope had a 584 mm wide mirror and a focal length of 3.3 meters. Images acquired by the telescope were transmitted to ground stations. The experiment module also contained five other scientific instruments, four of which shared the use of the telescope to make a variety of measurements of X-rays emitted by stellar objects. The fifth instrument, independent of the telescope, measured properties of X-rays beyond the telescope's energy range.

Project Results – Launched from Kennedy Space Center, Cape Canaveral, Florida on November 13, 1978. The spacecraft was injected into a near circular orbit with an inclination of 23.5 degrees and a period of 95.3 minutes. Apogee was 543 and perigee was 522.

Major Participants – HEAO-B was built by TRW Defense and Space Systems Group, Redondo Beach, California under the direction of NASA's Marshall Space Flight Center, Huntsville, Alabama. A consortium responsible for the five experiments included scientists from Harvard University/ Smithsonian Astrophysical Observatory, Massachusetts Institute of Technology, Columbia University, and NASA. American Science and Engineering of Cambridge, Massachusetts, handled the overall design, fabrication, and integration of the experiments. TRW/DSSG integrated the individual experiments into the spacecraft to form the observatory, assisted with the checkout and launch of HEAO-B at Kennedy Space Center, and handled contractor activities at the control center of the NASA Goddard Space Flight Center.

Key Spacecraft Personnel		Affiliation
PM	F. A. Speer	NASA-MSFC
PS	S. S. Holt	NASA-GSFC
SC	A. G. Opp	NASA Headquarters
MG	R. E. Halpern	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Monitor Proportional Center	PI	R. Giacconi	SAO
	OI	H. Tananbaum	SAO
	OI	G. W. Clark	Massachusetts Institute of Technology
	OI	S. S. Holt	NASA-GSFC
	OI	R. Novick	Columbia University
High-Resolution Imager	PI	R. Giacconi	SAO
	OI	H. Tananbaum	SAO
	OI	G. W. Clark	Massachusetts Institute of Technology
	OI	S. S. Holt	NASA-GSFC
	OI	R. Novick	Columbia University
Crystal X-Ray Spectrometer	PI	R. Giacconi	SAO
	OI	H. Tananbaum	SAO
	OI	G. W. Clark	Massachusetts Institute of Technology
	OI	S. S. Holt	NASA-GSFC
	OI	R. Novick	Columbia University
Imaging Proportional Counter	PI	R. Giacconi	SAO
	OI	H. Tananbaum	SAO
	OI	G. W. Clark	Massachusetts Institute of Technology
	OI	S. S. Holt	NASA-GSFC
	OI	R. Novick	Columbia University
Solid State Detector	PI	R. Giacconi	SAO
	OI	H. Tananbaum	SAO
	OI	G. W. Clark	Massachusetts Institute of Technology
	OI	S. S. Holt	NASA-GSFC
	OI	R. Novick	Columbia University

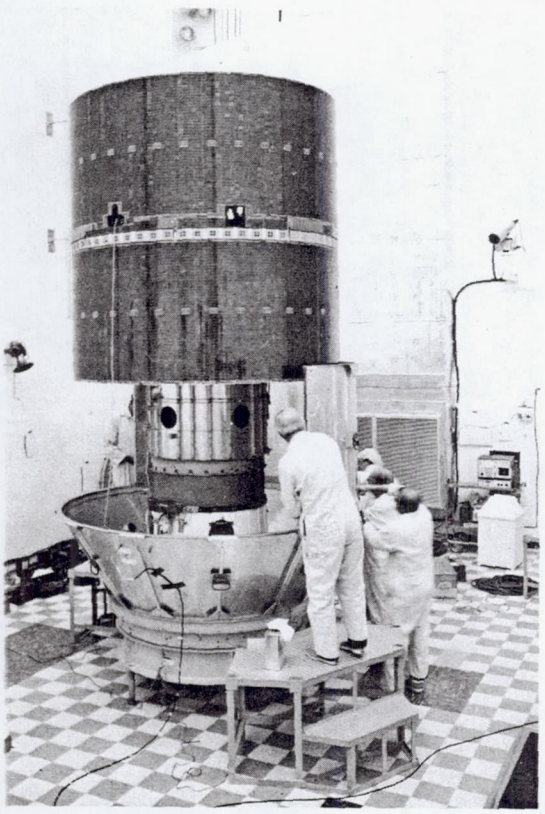
NATO III-C

Launch Vehicle – Delta 2914 – A three-stage Delta with an overall length of approximately 35 meters and a diameter of 2.4 m, not including the strap-ons. The first stage was an extended long-tank Thor booster powered by an RS-27 liquid oxygen and RJ-1 kerosene, supplemented by nine TMX-354-5 Castor II solid propellant strap-on rockets. The second stage was powered by a TRW-201 liquid-fuel, pressure-fed, rocket engine. The third stage was a spin-stabilized Thiokol TE-364-4 solid propellant motor.

Spacecraft Description – Drum-shaped, the NATO III-C was about 2.2 meters in diameter, 2.23 meters long, and had an overall length of 3.1 meters with antennas extended. At launch it weighed 720 kg, and after firing its on-board apogee kick motor, the weight reduced to 376 kg.

Project Objectives – The satellite was to provide an in-orbit backup to the NATO III-A and -B satellites in the NATO Integrated Communications System (NICS). The NATO Satcom System Control Center in Belgium near Supreme Headquarters, Allied Powers, Europe (SHAPE) scheduled and controlled all allied nations communications via the NATO satellites.

NATO III-C communications satellite was to serve the North Atlantic Treaty Organization. It was to orbit the Earth once every 24 hours, "synchronized" with the 24-hour Earth rotation period.



Spacecraft Payload – NATO III-C used three 20-watt traveling wave tubes with narrow-beam horn antennas permitting high capacity transmission on three channels to and from relatively small ground stations. Unique "nod and tilt" antenna design kept the satellite's antennas pointed at the desired ground position. NATO III-C received, translated frequency, and retransmitted voice, telegraph, facsimile, and wideband digital data.

Project Results – NATO III-C was launched by NASA from Kennedy Space Center, Cape Canaveral, Florida, on November 19, 1978. It was in geosynchronous orbit of 35,891 km near the Equator with an inclination of 4.3 degrees.

Major Participants – The NATO III program was managed by the U.S. Air Force Space and Missile Systems Organization (SAMSO) for NATO. Ford Aerospace produced the spacecraft, and McDonnell-Douglas Astronautics Corporation provided the Delta launch vehicle. The NASA Goddard Space Flight Center and the Kennedy Space Center were responsible for integration and launch operations.

ANIK-B/TELESAT-D

Launch Vehicle – Three-stage 3914 Delta. With a lift-off weight of 190,972 kg, the Delta launch vehicle was 35.4 meters high and had a diameter of 2.4 m without the attached solid propellant strap-on rockets. The lift-off thrust was 2,062,671 newtons from the main engine plus nine Castor IV solids. The first stage was a McDonnell Douglas extended long-tank Thor booster with nine strap-on Thiokol solid-fuel rocket motors. The Thor was powered by a Rocketdyne RS-27 engine using liquid oxygen and RP-1 kerosene. The height of the first stage was 21.3 m. The second stage was powered by a TRW TR-201 liquid-fuel, pressure-fed engine which was gimbal-mounted to provide pitch and yaw control. Second stage height was 7 m, and 1.4 m in diameter. The third stage was a Thiokol TE-364-4 spin stabilized, solid-propellant motor with a height of 1.8 m and a diameter of 0.95 m.

Spacecraft Description – ANIK-B/Telesat-D was 2.16 m in diameter and 6.43 m high with a lift-off weight of 922 kg. Its cylindrical body was covered with solar panels which provided the primary power for communications operations. An on-board apogee kick motor was used to achieve final orbit. The satellite was spin stabilized to maintain proper orientation.

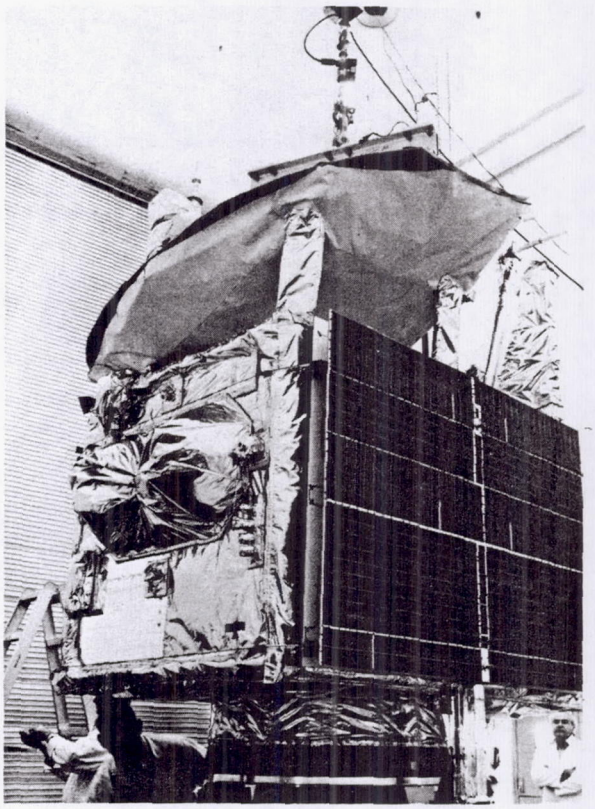
Project Objectives – The satellite replaced ANIK-A1/Telesat-A which was launched in November 1972, and was positioned at 109 degrees W longitude over the Equator, due south of California. ANIK-B/Telesat-B was to provide point-to-point voice, TV, and data communications traffic to Canada's 10 provinces.

Spacecraft Payload – In addition to 12 commercial channels in the 4 to 6 GHz frequency bands, ANIK-B/Telesat-D had four channels operating in the 12 and 14 GHz frequencies. The entire capacity of these two higher frequency bands was to be leased to Canada's Department of Communications for 14 pilot projects, all intended to evaluate the use of satellites for reaching remote locations equipped with small ground stations. The earth terminals were small enough to be mounted on the roofs or in the parking lots of user offices.

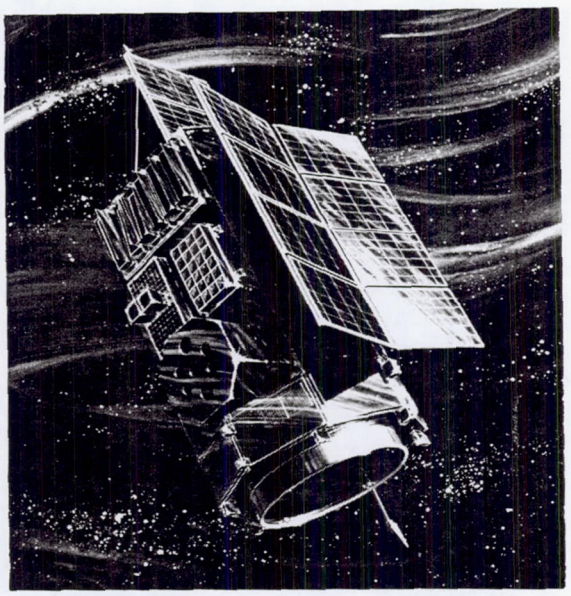
Project Results – ANIK-B/Telesat-D was launched from Cape Canaveral, Florida, on December 16, 1978. Several days after launch, the satellite was placed into an equatorial, near-circular orbit of 35,896 km.

Major Participants – The ANIK-B/Telesat-D was developed and built for Telesat Canada Ltd., Ottawa, Ontario, Canada, by RCA Astro-Electronics, Princeton, New Jersey. The Delta launch vehicle was managed by the Goddard Space Flight Center, Greenbelt, Maryland. Prime contractor for Delta and launch operations was McDonnell Douglas Astronautics Co., Huntington Beach, California. Tracking, transmission, and reception of data from the satellite was provided by the Telesat Earth station near Allan Park, Ontario, about 130 km west of Toronto, Canada.

Technicians perform pre-launch checkout of the Telesat–D (ANIK-B) spacecraft in the Delta Spin Test Facility on Cape Canaveral.

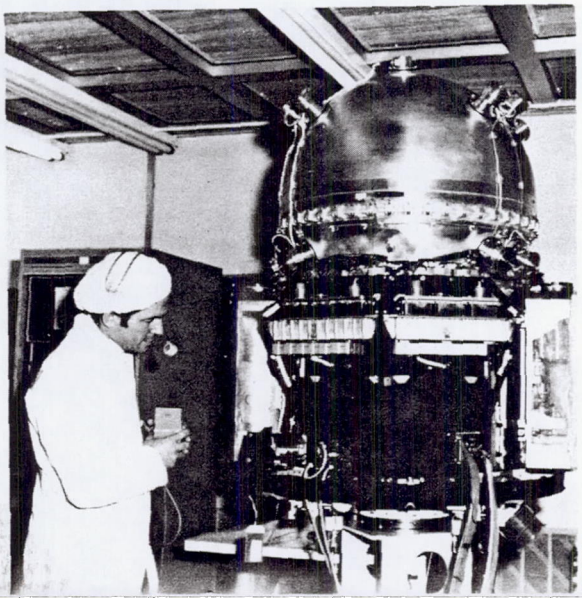


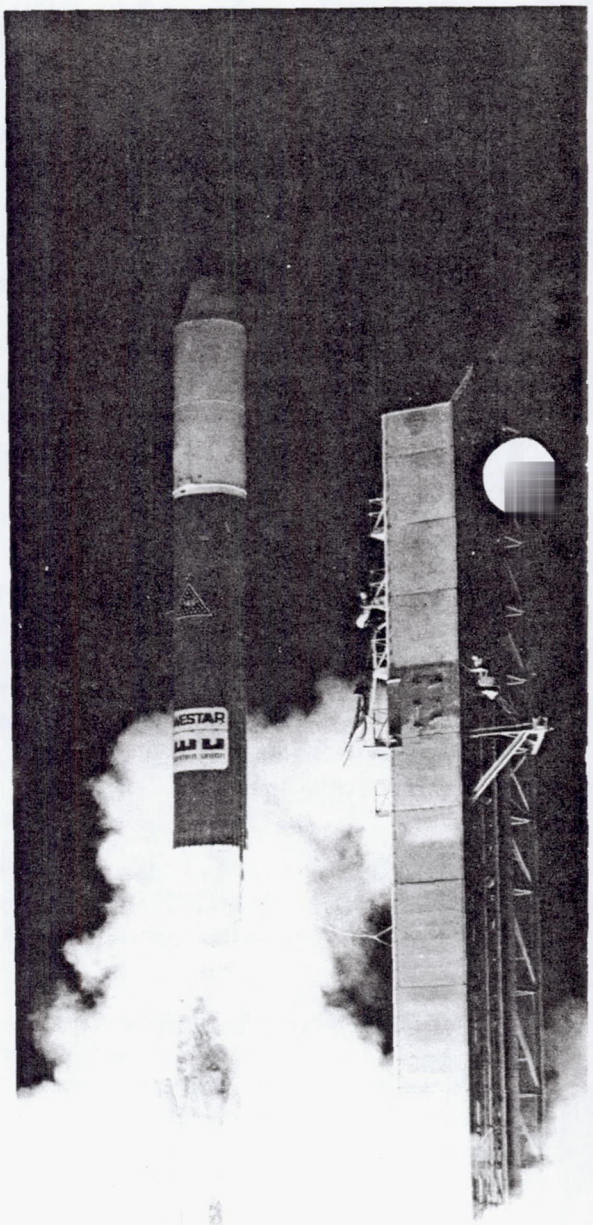
1978



Artist's sketch of the High Energy Astronomy Observatory-3, launched on September 20, 1979.

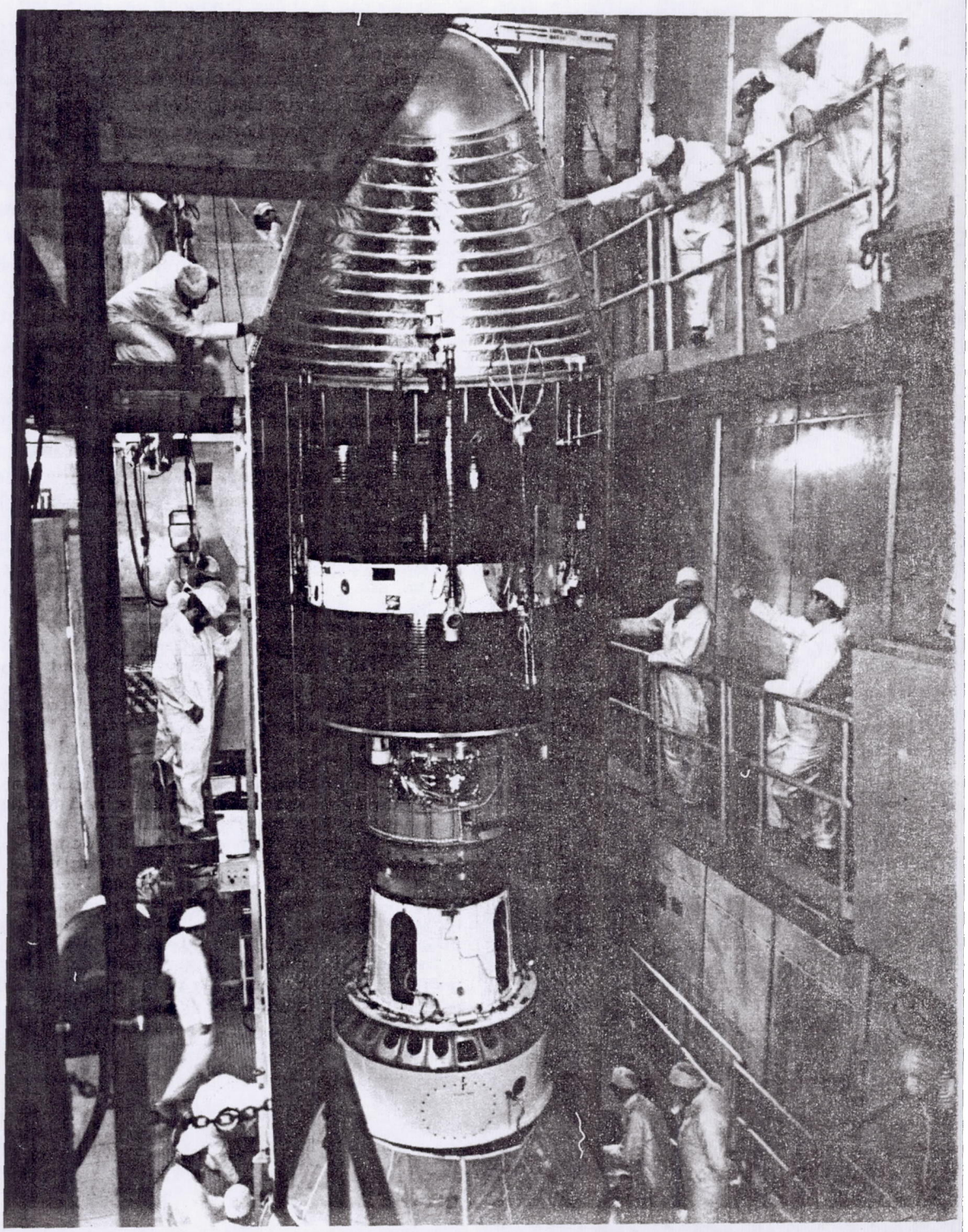
Preflight testing of UK-6 at the Marooni Space and Defence Systems, Ltd., at Portsmouth, England.





Western Union's WESTAR-C was launched into orbit on August 9, 1979.

1979



SCATHA (Spacecraft Charging in High Altitudes) is enclosed in nose fairing on top of the Delta rocket. NASA launched this Air Force research satellite on January 30, 1979.

SPACECRAFT CHARGING AT HIGH ALTITUDES (SCATHA)

Launch Vehicle–Delta 2914.

Spacecraft Description–Cylindrical main structure 6 feet in diameter and 6 feet high, from which a number of booms of various lengths were deployed. Cylinder's external walls were covered by solar cells to provide SCATHA with 300 watts of electrical power. The structure housed an apogee kick motor. Weight at launch, 1,444 pounds; in orbit, 787 pounds.

Project Objectives–SCATHA's objective was to investigate the electrical charging effects on spacecraft in high-altitude orbits caused by their passing through the Earth's magnetic field and encountering or attracting the charged particles which collect in that field. SCATHA data was expected to provide data useful in developing design and test requirements for future satellites.

Spacecraft Payload–SCATHA carried twelve experiments to characterize the electric and magnetic fields and the charged particle environment of the spacecraft: charging electrical effects analyzer and satellite surface potential monitor, Aerospace Corp.; spacecraft electrical sheath fields and energetic proton detector, Aerospace Corp.; high-energy particle spectrometer, Lockheed-Palo Alto; particle beam systems, AF Geophysical Lab; rapid-scan particle detector, Air Force Geophysical Lab; thermal electronic measurements, Air Force Geophysical Lab; light ion mass spectrometer, Lockheed-Palo Alto; energetic ion spectrometer, Lockheed-Palo Alto; particle detectors, University of California-San Diego; electric field detectors, NASA-Goddard; magnetic field monitor, NASA-Goddard; and thermal control/contamination experiment, Air Force Materials Lab/Aerospace Corp.

Project Results–SCATHA was lauched from Cape Canaveral aboard a Delta vehicle on January 30, 1979 and placed in a 27,000 by 43,000 kilometer orbit at an inclination of 7.6 degrees.

Major Participants–Space Test Program management, U.S. Air Force Space Division; spacecraft prime contractor, Martin Marietta, Denver; launch vehicle and launch management, NASA; launch vehicle prime contractor, McDonnell Douglas.

NASA Headquarters--John F. Yardley, Associate Administrator, Office of Space Transportation Systems; Joseph B. Mahon, Director of Expendable Launch Vehicle Systems, OSTS; Peter T. Eaton, Manager, Delta Program, OSTS.
Goddard Space Flight Center--Dr. Robert S. Cooper, Director; Robert E. Smylie, Deputy Director; Robert N. Lindley, Director, Project Management; Robert Baumann, Associate Director for Space Transportation; David W. Grimes, Delta Project Manager; William R. Russell, Deputy Delta Project Manager, Technical; Robert Goss, Manager, Delta Mission Analysis and Integration Manager; William Hawkins, Mission Operations and Network Support Manager; Ray Mazur, Mission Support.
Kennedy Space Center--Lee R. Scherer, Director; Gerald D. Griffin, Deputy Director; Dr. Walter J. Kapryan, Director of Space Vehicles Operations; George F. Page, Director, Expendable Vehicles; W.C. Thacker, Chief, Delta Operations Division; Wayne L. McCall, Chief Engineering, Delta Operations Division; John J. Dunn, Spacecraft Coordinator.
DOD/USAF--Lt. Col. John Durrett, SCATHA Spacecraft Program Manager USAF/SAMSO.

STRATOSPHERIC AEROSOL AND GAS EXPERIMENT (SAGE) (Applications Explorer Mission–2)

Launch Vehicle–Scout.

Spacecraft Description–Hexagonal structure 28 inches across and 25 inches high, atop which was mounted the SAGE instrument module. Two 24-square-foot solar arrays deployed in winglike fashion from the main body.

Project Objectives–Measure the attenuation of solar radiation in the Earth's atmospheric layers to establish baseline data on aerosol and ozone global concentrations and to assess the effects of transient phenomena on these concentrations. The SAGE mission called for 10,000 measurements in the area between 72 degrees south latitude and 72 degrees north latitude.

Spacecraft Payload–Photometric device which measured attenuated solar intensity.

Project Results–SAGE was launched from Wallops Island, Virginia aboard a Scout launch vehicle on February 18, 1979 and placed in an orbit of 661 by 548 kilometers at an inclination of 54.9 degrees.

Major Participants–Program management, NASA-Goddard; launch management, NASA-Wallops Island; spacecraft integrator, Boeing Aerospace Co.; launch vehicle prime contractor, Vought.

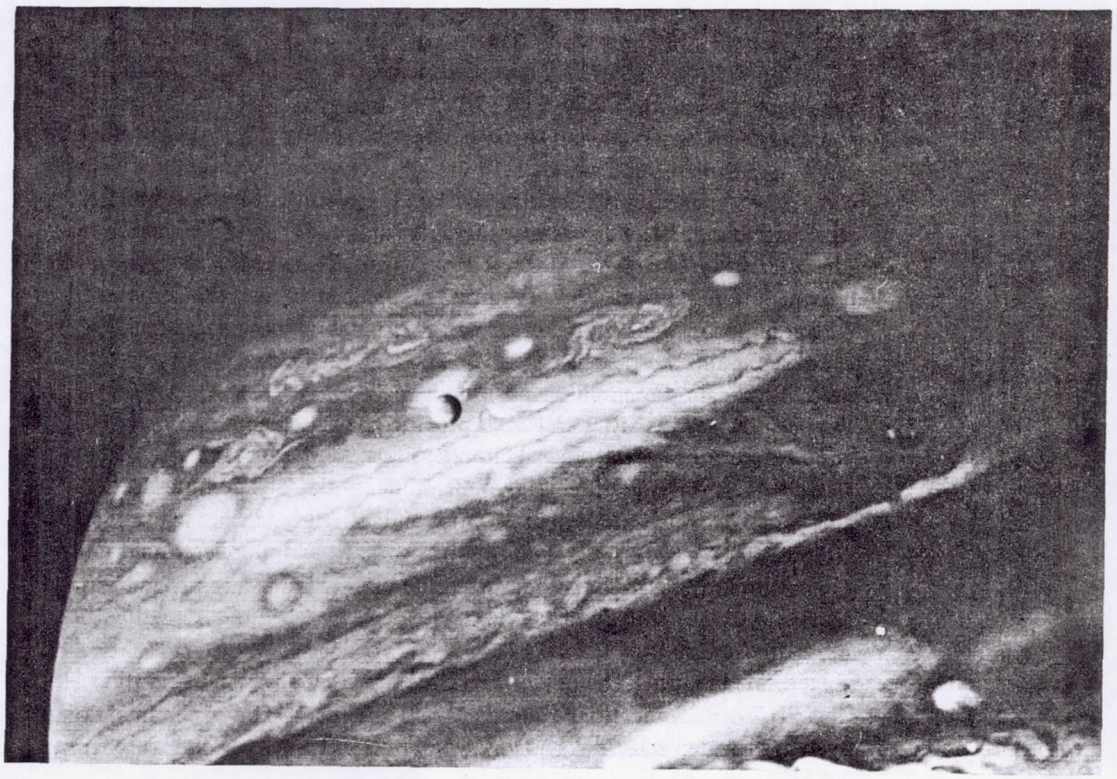
Key Spacecraft Personnel	Affiliation
PM C. Wagner	NASA-GSFC

Experiment	Experiment Personnel	Affiliation
Stratosphere Aerospace & Gas Experiment	PI M.P. McCormick	NASA-LARC
	PM C.M. MacKenzie	NASA-GSFC
	PS R.S. Fraser	NASA-GSFC
	MG D.S. Diller	NASA Headquarters
	SC S.H. Melfi	NASA Headquarters

During 1979, some of the most remarkable pictures ever obtained from outer space were produced by NASA's spacecraft.



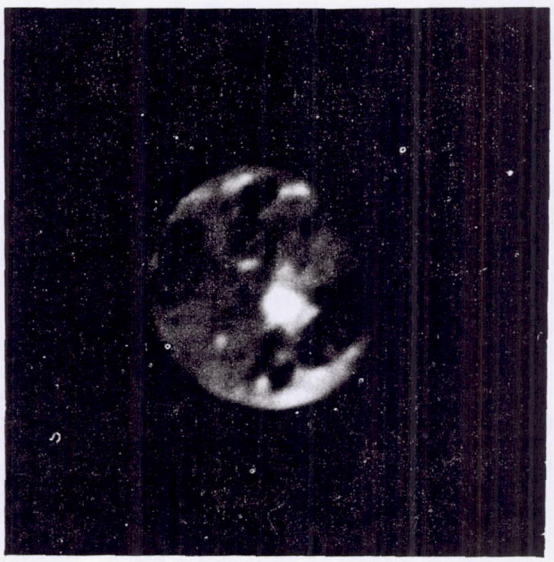
Image of planet Venus by the Pioneer Venus Orbiter from an altitude of 65,000 km. The spacecraft began its orbit of Venus on December 4, 1978. This image was taken during orbit number 41.



Jupiter with its satellites Io and Europa. Io is about 350,000 km above Jupiter's Great Red Spot; Europa is about 600,000 km above Jupiter's clouds.



When Voyager I was 5.7 million miles from Jupiter, this dramatic photograph was obtained, showing the planet's Great Red Spot and its surroundings. Cloud details as small as 160 km across can be seen.



Voyager I took this picture of Jupiter's satellite Ganymede from a distance of some 8 million km. It is the largest of Jupiter's thirteen satellites.

NAVY FLEET SATELLITE COMMUNICATIONS-B (FLTSATCOM-B)

Launch Vehicle—Atlas-Centaur. Two-stage, liquid-fueled vehicle. First stage was Atlas vehicle, 21.3 m long, with a MA-5 engine system developing 1,917,288 Newtons at lift-off. The Centaur second stage was 14 m long; its two engines produced 133,400 Newtons.

Spacecraft Description—The FLTSATCOM consisted of two stacked hexagonal modules, antennas, and two winglike solar arrays. The hexagonal body is 2.4 meters across and stands 1.27 m high. At launch, the satellite weight was 1,884 kg; in-orbit weight was 987 kg. It had an 18-turn helical UHF receive antenna and a 4.8 meter deployable parabolic UHF transmit antenna. The solar array provided 1,200 watts of power. Three-axis stabilization was provided by redundant, body-mounted momentum wheels that interacted with monopropellant hydrazine thrusters to stabilize the spacecraft's attitude and point the antennas at the Earth's center. Hydrazine jets were also used to relocate the satellite's position.

Program Objectives—FLTSATCOM provided worldwide high-priority UHF communications between naval aircraft, ships, submarines, and ground stations, SAC and the Presidential command network. The communications subsystem provided more than 30 voice and 12 teletype channels designed to serve small mobile users such as ships, aircraft, and mobile ground units. Operation in the UHF band permitted the use of simple aircraft and submarine antennas with hemispheric coverage patterns, thus eliminating the need for satellite tracking.

Spacecraft Payload—The payload module of the satellite included the UHF and SHF communications equipment and antennas. The communications system provided relay links as follows: one 25 kHz fleet broadcast channel and SHF beacon, nine 25 kHz fleet relay channels, twelve 5 kHz Air Force band channels, and one 500 kHz DoD wideband channel. The UHF receive band spanned the 292 to 400 MHz range and transmitted signals were in the 244 to 279 MHz band.

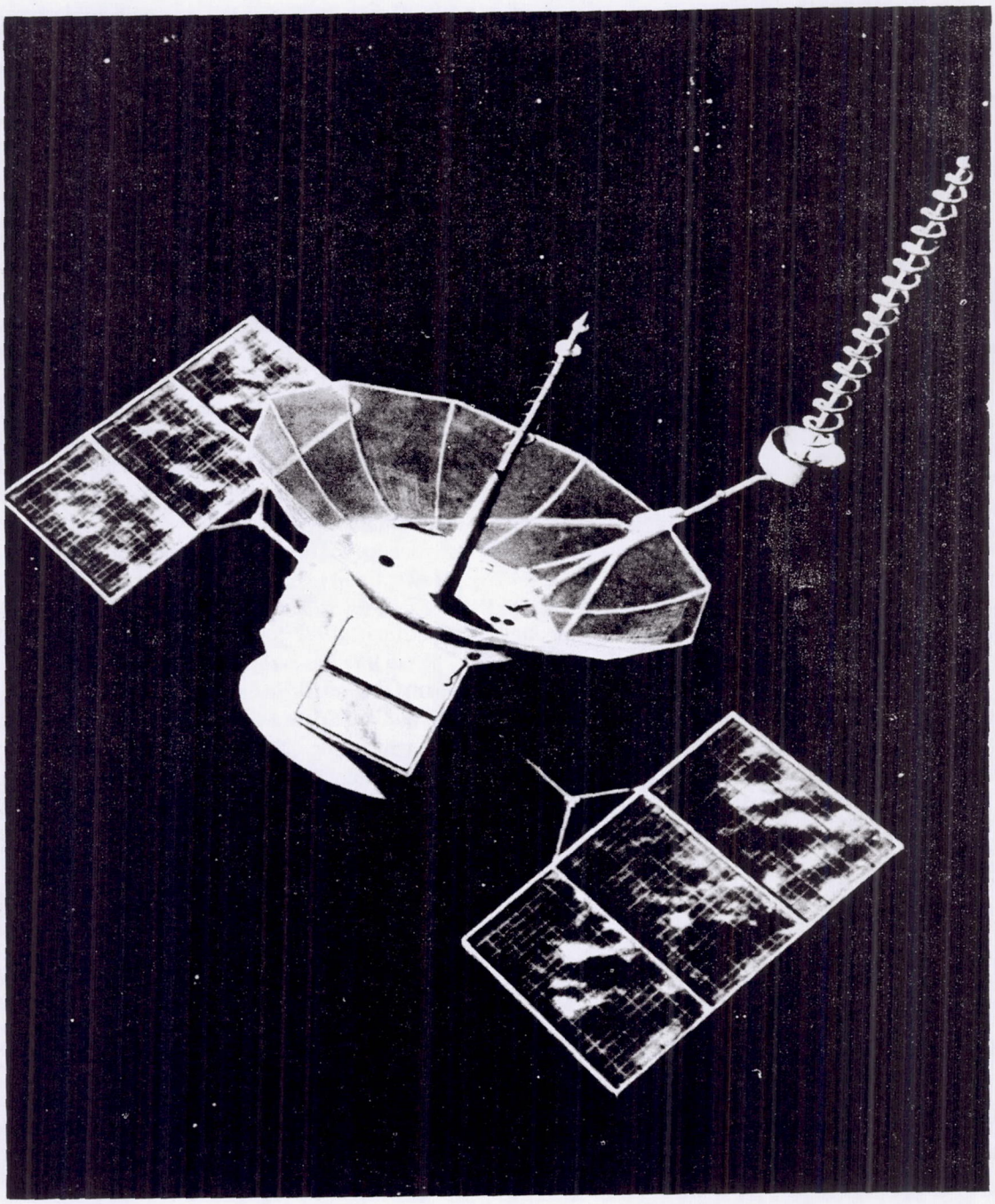
Project Results--FLTSATCOM-B was launched May 4, 1979 aboard an Atlas Centaur launch vehicle from Cape Canaveral. It was placed in geosynchronous orbit and put in service at its operational station at 23 degrees West longitude--50th launch of Atlas/Centaur.

Major Participants--Program management, Naval Electronics Systems Command; Space segment procurement and launch, U.S. Air Force Space and Missile Systems Organization; spacecraft prime contractor, TRW; launch vehicle prime contractor, General Dynamics. Lewis Research Center Launch Vehicle Management.

NASA Headquarters--John F. Yardley, Associate Administrator for Space Transportation Systems; Joseph B. Mahon, Director, Expendable Launch Vehicles; F.R. Schmidt, Manager, Atlas Centaur Launch Vehicles.

Lewis Research Center--Dr. John F. McCarthy, Jr., Director; Dr. Seymore C. Himmell, Associate Director; Lawrence J. Ross, Director, Launch Vehicles; J.E. Patterson, Chief, Vehicles Engineering Division; C.B. Wentworth, Chief, Program Integration Division; Kenneth A. Adams, FLTSATCOM Mission Project Engineer; Frank L. Manning, FLTSATCOM Vehicle Engineering.

Kennedy Space Center--Lee R. Scherer, Director; Gerald D. Griffin, Deputy Director; Dr. Walter J. Kapryan, Director, Shuttle Operations, George F. Page, Director, Cargo Operations; John Gossett, Chief, Centaur Operations Division; Barry Olton, Spacecraft Coordinator.



Artist's concept of FLTSATCOM-B, a U.S. Navy/Department of Defense communications satellite. This satellite has enabled communications between naval aircraft, ships, submarines, ground stations, and Strategic Air Command elements and presidential command networks.

UK-6 (ARIEL 6)

Launch Vehicle–Four-stage Scout D. The launch marked Scout's 100th use.

Spacecraft Description–Cylindrical structure 27.4 inches in diameter and 51.5 inches high, with a spherical cosmic ray detector mounted at the top of the cylinder and two X-ray experiments mounted on its sides. Four solar arrays deployed from the base at 90-degree angles provided 80 watts of power. The span across the solar array booms was nine feet. Spacecraft weight was approximately 340 pounds.

Project Objectives–Investigation of high-energy astrophysics to provide information on the conditions of the source and the processes of nucleosynthesis that have occurred in high-energy objects throughout the universe.

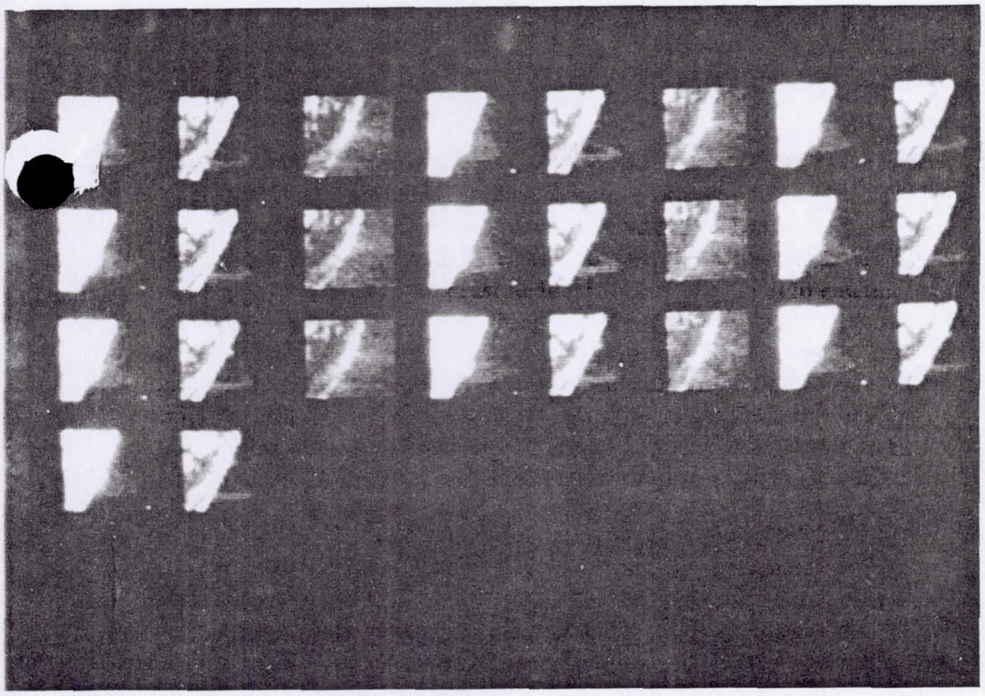
Spacecraft Payload–Three science experiments and two technology experiments. This included a cosmic ray detector (Bristol University) to measure ultra-heavy components of cosmic radiation with particular emphasis on the charge region of atomic weights above 30; an X-ray experiment (Leicester University) operating the energy range of 1.2 to 50 keV; and an X-ray experiment (Birmingham University and the University College of London's Mullard Space Science Laboratory) operating in the range of 0.1 to 2 keV. Two technology experiments were also aboard, one designed to assess the performance of new types of solar cells, the other to investigate the radiation susceptibility of CMOS electronics package.

Project Results–UK-6 was launched from Wallops Island, Va. aboard a Scout vehicle on June 2, 1979 and placed in 658 by 596-km orbit at 55 degrees inclination. The satellite was designed to operate for approximately two years.

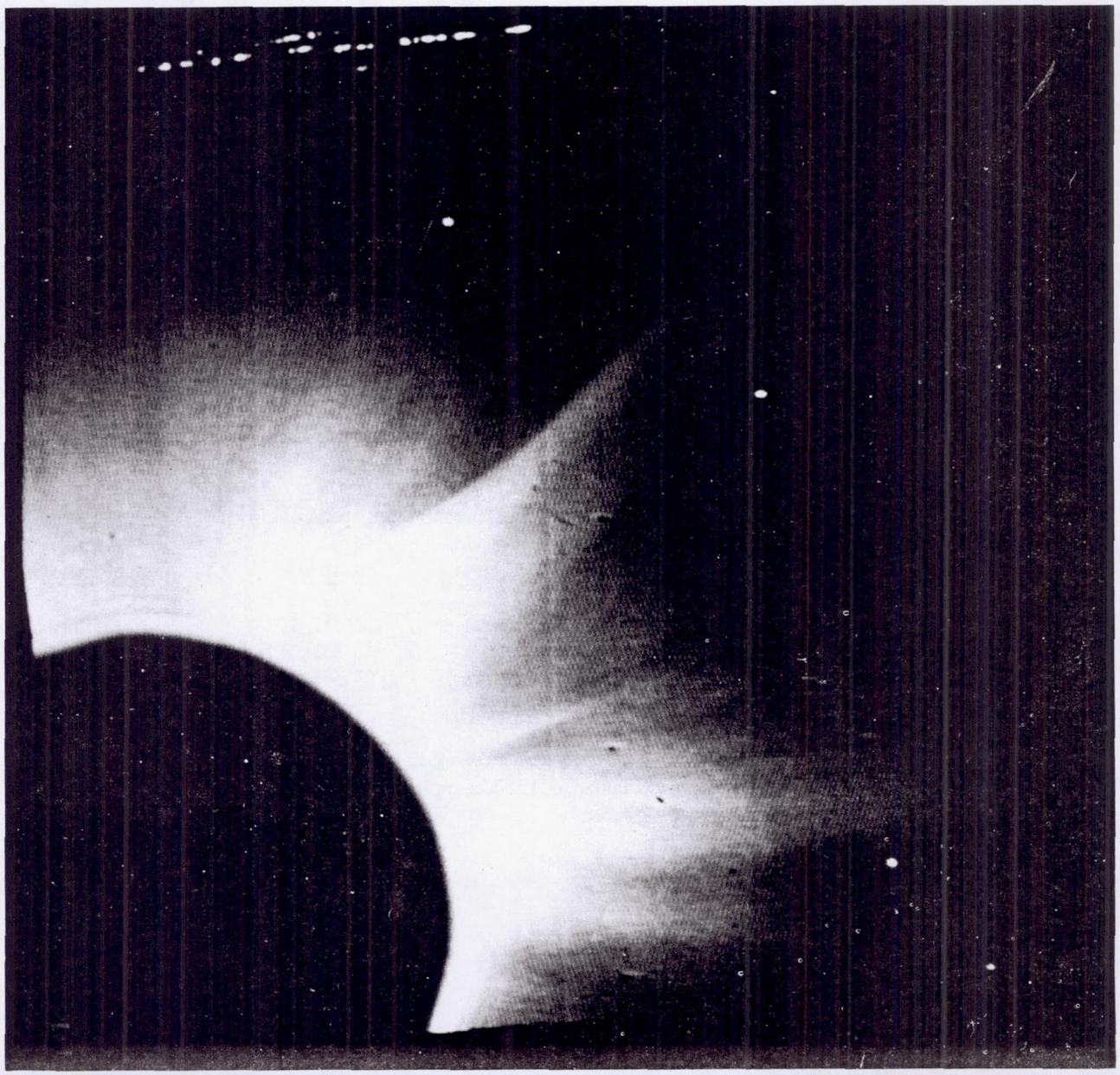
Major Participants–Project management, U.K. Science Research Council; Project science, Mullard Space Science Laboratory, University College, London; Spacecraft contractor, Marconi Space and Defense Systems; Launch management, NASA Langley Research Center; Launch vehicle contractor, Vought.

NASA Headquarters--John F. Yardley, Associate Administrator for Space Transportation Systems; Joseph B. Mahon, Director, Expendable Launch Vehicles Program; Paul Goozh, Scout Program Manager.
Langley Research Center--Donald P. Hearth, Director; Lee R. Foster, Jr., Head, Scout Project Office; Samuel J. Ailor, Head, Scout Systems; Abraham Leiss, Head, Scout Technical Resources; Joseph B. Talbot, NASA Project Manager; Jon L. Van Cleave, Quality Assurance and Reliability; Clyde W. Winters, Launch Operations.
Goddard Space Flight Center--Dr. Robert S. Cooper, Director; K.B. Blaney, NASA Network Support Manager.
Wallops Flight Center--Robert L. Krieger, Director; William L. Lord, Test Director; William T. Burns, Project Engineer; F. Ronald Sawyer, Range Safety Officer.
United Kingdom--J.E. Foster, Program Manager, Appleton, Laboratory; Dr. J.L. Culhane, Project Scientist, Mullard Space Science Laboratory, University College London; Dr. R.K. Burdett, Experiments Coordinator, Science Research Council; B.W. Jacobs, Project Manager, Ministry of Defence; A.J. Rogers, Control Centre Manager, Appleton Laboratory; R.C. Cock, Project Officer, Space Department, Royal Aircraft Establishment.
Principal Science Investigators--Prof. P.H. Fowler, Bristol University; Prof. K.A. Pounds, Leicester University; Prof. R.L.F. Boyd, Mullard Space Science Laboratory, University College, London; Prof. A.P. Willmore, Birmingham University.

1980



The Solar Maximum Mission Satellite obtained these pictures: (left) Solar flare activities on July 1, 1980. (Below) A striking view of the solar corona. Shortly after this picture was taken on June 2, 1980, a solar flare occurred on the Sun at about 3:00 o'clock in this picture (southwest).



FLTSATCOM-C

Launch Vehicle – The Atlas Centaur (AC-49), standing approximately 39.9 m (131 ft.) high, consisted of an Atlas SIV-3D booster and Centaur D-1AR second stage. The Atlas booster developed 1,920 kilonewtons (431,300 lb.) of thrust at lift-off using two 822,920-newton (185,000-lb.) thrust booster engines, one 266,890-N (60,000-lb.) thrust sustainer engine, and two vernier engines, developing 2,890 N (650 lb.) thrust each. The two RL-10 engines on Centaur produced a total of 133,450 N (30,000 lb.) thrust. Both the Atlas and the Centaur 3 m (10 ft.) in diameter.

Spacecraft Description – The FLTSATCOM satellites, built in Redondo Beach, Calif. by the Defense and Space Systems Group of TRW, Inc., are 6.7 meters (22 ft.) tall and weigh 1,876 kilograms (4,136 lbs.) at liftoff and 1,005 kg (2,216 lbs.) after apogee motor firing.

Program Objectives – The FLTSATCOM satellites are the spaceborne portion of a worldwide Navy, Air Force, and Department of Defense communications system that enables communicating between naval aircraft, ships, submarines, ground stations, Strategic Air Command elements, and presidential command networks. The Atlas Centaur (AC-49) launch vehicle placed FLTSATCOM-C into a highly elliptical orbit of 167 by 35,970 kilometers (104 by 22,351 miles). After reorientation of the satellite, a solid propellant rocket motor aboard the spacecraft was fired to circularize the orbit at a synchronous altitude of 35,788 km (22,237 mi.). At that altitude, because the speed of the spacecraft in orbit matches the rotational speed of the Earth, the satellite remained in position over one spot on the equator.

Spacecraft Payload – The satellite system provided 23 ultra high frequency communication channels and one super high frequency channel. Placed in a geostationary orbit at 172 degrees east longitude above the equator, FLTSATCOM-C provided two-way communications in the 240 to 400 MHz frequency band, between any two points on Earth visible from its orbital location.

Test Results – The FLTSATCOM-C spacecraft was successfully launched into a synchronous transfer orbit by the Atlas-Centaur AC-49 at 2026 hours EST from the ETR Launch Complex 36 on January 17, 1980.

The transfer orbit parameters were as follows:

	Actual	Nominal
Inclination (degrees)	26.3557	26.3526
Eccentricity	0.732301	0.732279
Apogee Height (km)	35975.9	35971.5
Perigee Height (km)	166.96	166.92

The spacecraft apogee kick motor was successfully fired at fifth apogee on January 20, 1980, injecting the spacecraft into the desired synchronous orbit.

NOAA-6

Launch Vehicle–Atlas E/F. NOAA-6 used a TE-364-15 solid motor as an apogee kick motor. The apogee kick assembly was attached to the spacecraft and remained with it in orbit after expending approximately 1,500 pounds of propellant.

Spacecraft Description–NOAA-6 was nearly identical to TIROS-N. The spacecraft, including the apogee kick motor, in the launch configuration was 371 cm high and 188 cm in diameter and weighed nominally 1,405 kg. On-orbit, with the apogee kick motor and reaction-control equipment expendables consumed, the satellite had a nominal weight of 723 kg.

The spacecraft 'bus' consisted of the following subsystems: structure-thermal, power, attitude determination and control, and communications and data handling.

Project Objectives–Work as a companion to TIROS N to provide continuous coverage of the Earth and provide high-accuracy worldwide meteorological data.

Spacecraft Payload–Onboard instrumentation included an Advanced Very High Resolution Radiometer (AVHRR) to provide timely data on day and night sea surface temperatures, ice, snow, and cloud conditions.

The satellite also carried a data collection and platform location subsystem which could receive, process, and store data from fixed and moving platforms, including free-floating balloons and buoys, for transmission to a central processing facility.

An atmospheric sounding system provided a vertical temperature profile of the atmosphere from the Earth's surface to near the top of the atmosphere (1 mb) and a moisture vapor content profile from the surface to the tropopause. A space environment monitor provided for continuous measurements of the proton alpha and electron flux activity near Earth. This instrument was an extension of the solar portion monitor package aboard the earlier ITOS satellites.

Project Results–NOAA-6 was launched from Vandenberg AFB, Calif. on June 27, 1979 and placed in a polar orbit of 828 by 810 km.

Major Participants–Meterological satellite for the National Oceanic and Atmospheric Administration; pre-launch program management, NASA; launch vehicle operations, NASA Western Launch Operations; Spacecraft prime contractor, RCA AstroElectronics; spacecraft operations and data management, National Oceanic and Atmospheric Administration; Launch vehicle prime contractor, General Dynamics.

Major Participants–

NOAA

David S. Johnson, Acting Assistant Administrator, Oceanic and Atmospheric Services; Clifford A. Spohn, Acting Director, National Environmental Satellite Service; George H. Ludwig, Director, Office of Operations, NESS; E. Larry Heacock, Director, Office of Systems Integration, NESS; Arthur Schwalb, Polar Orbiting Systems Group Head, NESS; Sheila C. Frey, NESS Liaison Office Program Assistant.

NASA Headquarters

Dr. Anthony J. Calio, Associate Administrator for Space and Terrestrial Applications; Samuel W. Keller, Deputy Associate Administrator for Space and Terrestrial Applications; Dr. Lawrence R. Greenwood, Director, Environmental Observations Division, Office of Space and Terrestrial Applications; M.L. Garbacz, Manager, Operational Meteorological Satellite Program; John F. Yardley, Associate Administrator for Space Transportation Systems; J.B. Mahon, Director Expendable Launch Vehicles Program; J.A. Salmanson, Manager, Atlas-F.

Goddard Space Flight Center

Dr. Robert Cooper, Director; Robert Lindley, Director, Project Management Directorate; G.A. Branchflower, Project Manager; W. Redisch, Deputy Project Manager, Technical; R.J. Flick, Deputy Project Manager, Resources; W.M. Peacock, Spacecraft Manager, C.E. Thienel, Instrument Manager; J.F. Corrigan, Launch Vehicle Manager; W.A. Hembree, Mission Operations Manager.

Key Spacecraft Personnel		Affiliation
PM	G. A. Branchflower	NASA-GSFC
PS	A. Arking	NASA-GSFC
MG	M. L. Garbacz	NASA Headquarters

Experiment	Experiment Personnel		Affiliation
Advanced High Resolution Radiometer	PI	Ness Staff	NOAA-NESS
	CO	W. E. Shenk	NASA-GSFC
Operational Vertical Sounder	PI	Ness Staff	NOAA-NESS
	PI	Ness Staff	NOAA-NESS
Data Collection System	PI	D. J. Williams	NOAA-ERL
Space Environmental Monitor	PI	H. H. Sauer	NOAA-ERL
	OI	C. O. Bostrom	Applied Physics Laboratory

Launch Vehicle–Delta 2914; three stages, 396,700 pounds of thrust at lift-off.

Spacecraft Description–Spin-stabilized cylinder weighing 577 kg. Atop the cylinder was a spoon-shaped despun antenna capable of providing coverage of the 48 contiguous states; it could be directed to cover Alaska or Puerto Rico; a separate spot beam was used for Hawaii. Solar cells covering the vertical portion of the cylinder provided more than 300 watts of power to Westar-C. The spacecraft was approximately 75 inches in diameter; its main body approximately 62 inches high, and its overall height with antenna deployed was approximately 11.8 feet.

Project Objectives–Provide increased capacity for Western Union's Westar domestic satellite communications system.

Spacecraft Payload–Twelve-transponder system, each with 36 MHz bandwidth. The system operated in the 4 to 6 GHz range. Each transponder could carry one color TV picture or 1,200 one-way voice channels.

Project Results–WESTAR-C was launched aboard a Delta vehicle from Cape Canaveral on August 9, 1979 and placed in geosynchronous orbit at 91 degrees West longitude, due south of New Orleans.

Major Participants–System owner and operator, Western Union; spacecraft prime contractor, Hughes Aircraft; launch operations, NASA-Kennedy Space Center; launch vehicle prime contractor, McDonnell Douglas.

NASA Headquarters

John F. Yardley, Associate Administrator for Space Transportation Systems; Joseph B. Mahon, Director, Expendable Launch Vehicle Systems; Peter T. Eaton, Manager Delta Program.

Goddard Space Flight Center

Robert E. Smylie, Acting Director; John H. Boeckel, Acting Director, Project Management; David W. Grimes, Delta Project Manager; Robert Goss, Manager, Delta Mission Analysis and Integration; Frank J. Lawrence, Westar-C Mission Integration Manager; William Hawkins, Mission Operations and Network Support Manager; Ray Mazur, Mission Support.

Kennedy Space Center

Lee R. Scherer, Director; F.A. Rigel, Acting Director, Cargo Operations; Chuck Gay, Director, Deployable Payloads Operations; Wayne L. McCall, Chief, Delta Operations Division; Gayle Hager, Spacecraft Coordinator.

HIGH ENERGY ASTRONOMY OBSERVATORY-3 (HEAO-3)

Launch Vehicle–Atlas-Centaur.

Spacecraft Description–A boxlike experiment module atop a hexagonal spacecraft equipment module. Two large solar arrays and one smaller solar array were attached to one side of the experiment module. They provided HEAO-3 with 415 watts of electrical power. A conical omnidirectional antenna was atop the spacecraft. Spacecraft weighed 2,898 kg.

Project Objectives–HEAO-3 carried two cosmic ray experiments and one gamma ray spectrometer to gather information on the origin, propagation, and acceleration mechanism for cosmic rays observed across the far reaches of space.

Spacecraft Payload–Three instruments: a high resolution gamma-ray spectrometer consisting of four high-purity germanium detectors, surrounded by a cesium-iodide detector which served as shield and collimator; a cosmic ray experiment consisting of five Cerenkov detectors with a variety of radiators and a four-tray neon flash tube hodoscope, each containing two perpendicular layers of 124 tubes each, which permit determination of particle paths; and a heavy nuclei experiment which used two multilayer ionization chambers and a Cerenkov detector to determine the energy and charge of individual particles.

NASA Headquarters

Dr. Thomas A. Mutch, Associate Administrator for Space Science; T. Bland Norris, Director, Astrophysics Programs; Richard E. Halpern, Manager, High Energy Payloads; Dr. Albert G. Opp, Program Scientist; John F. Yardley, Associate Administrator for Space Transportation Systems; F.R. Schmidt, Program Manager, Expendable Launch Vehicles; Dr. William Schneider, Associate Administrator for Space Tracking and Data Systems; Frederick B. Bryant, Manager, Space Tracking and Data Systems Network.

Marshall Space Flight Center

Dr. William R. Lucas, Director; Dr. Fred A. Speer, Manager, HEAO Project; Fred S. Wojtalik, Chief Engineer, HEAO Project; Charles H. Meyers, Manager, Spacecraft Office; Joseph B. Jones, Manager, Experiment Office; Tom Irby, HEAO-3 Observatory Manager; Dr. Tom Parnell, HEAO-3 Project Scientist.

Goddard Space Flight Center

Robert E. Smylie, Acting Director; Tecwyn Roberts, Director of Networks, Tracking and Data Acquisition; Albert G. Ferris, Director, Mission and Data Operations; Richard S. Costa, Mission Operations Systems Manager.

Kennedy Space Center

Richard G. Smith, Director; Gerald D. Griffin, Deputy Director; George F. Page, Director, Shuttle Operations; I.A. Rigell, Acting Director, Cargo Operations; Charles D. Gay, Director, Deployable Payloads Operations; John D. Gossett, Chief, Centaur Operations; Larry Kruse, Spacecraft Coordinator.

Lewis Research Center

Dr. John McCarthy, Director; Larry Ross, Director, Launch Vehicles; Edwin T. Muckley, HEAO Project Engineer.

Experiment	Experiment Personnel		Affiliation
Gamma-Ray Line Spectrometer	PI	A.S. Jacobson	NASA-JPL
	OI	J.R. Arnold	University of California, San Diego
	OI	A.E. Metzger	NASA-JPL
	OI	L.E. Peterson	University of California San Diego
Heavy Nuclei	PI	M.H. Israel	Washington University
	OP	E.C. Stone	California Institute of Technology
	OP	C.J. Waddington	University of Minnesota
	OI	W.R. Binns	McDonnell Douglas Corporation
	OI	J. Klarmann	Washington University
	OI	R.E. Vogt	California Institute of Technology
Cosmic Ray Isotope and Charge	PI	L. Koch	CENS
	OP	B. Peters	Danish Space Research Institute
	OI	J.P Meyer	CENS
	OI	D. Roussel	CENS
	OI	A. Soutoul	CENS
	OI	M. Casse	CENS
	OI	P. Mestreau	CENS
	OI	N. Lund	Danish Space Research Institute
	OI	K. Omo	Danish Space Research Institute
	OI	O. Corydon-Peterson	Danish Space Research Institute

MAGNETIC FIELD SATELLITE (MAGSAT)

Launch Vehicle—Scout G-1.

Spacecraft Description—Spacecraft was made up of two modules: a base module, which used the same octagonal structure as the Small Astronomy Satellite, and an instrument module containing science payload and instrumentation. Extending from the spacecraft were four solar array paddles which protruded from the main body in an "X"-shaped configuration, and a long (20-foot) scissors-type boom which deployed Magsat's two magnetometers to minimize magnetic interference from the spacecraft. The main body of Magsat was 63 inches high, with a diameter of 30 inches. Length from tip to tip of the deployed solar arrays was 134 inches. Spacecraft weight was approximately 400 pounds. Solar cells provided 160 watts of electrical power to the spacecraft and its experiments.

Project Objectives—Magsat's orbit enabled it to cover the globe every ten days. Additional information provided by Magsat included data such as geologic composition, rock formation temperatures, and geologic structure on a regional scale.

Spacecraft Payload—Two magnetometers: a cesium vapor, self-oscillating, four gas-cell, dual lamp magnetometer; and a vector magnetometer which used three ring-core fluxgate sensors operating at 25°C ± 1°C to provide accuracies of 3 gammas.

Project Results—Magsat was launched from Vandenberg AFB aboard a Scout G-l launch vehicle on October 30, 1979 and placed in a near-polar orbit of 352 by 578 kilometers.

Major Participants—Program management, NASA Goddard Space Flight Center; Science participation: scientists from the United States and eight other countries; Spacecraft contractor, Applied Physics Laboratory, Johns Hopkins University; Launch management, NASA Western Launch Operations; Launch Vehicle prime contractor, Vought Corp.

NASA Headquarters--Dr. Anthony J. Calio, Associate Administrator for Space and Terrestrial Applications; Pitt G. Thome, Director, Resource Observation Division; James P. Murphy, Magsat Program Manager; Dr. James V. Taranik, Magsat Program Scientist; John M. Yardley, Associate Administrator for Space Transportation System Acquisition; Joseph B. Mahon, Director, Expendable Launch Vehicle Systems; Paul E. Goozh, Scout Program Manager.

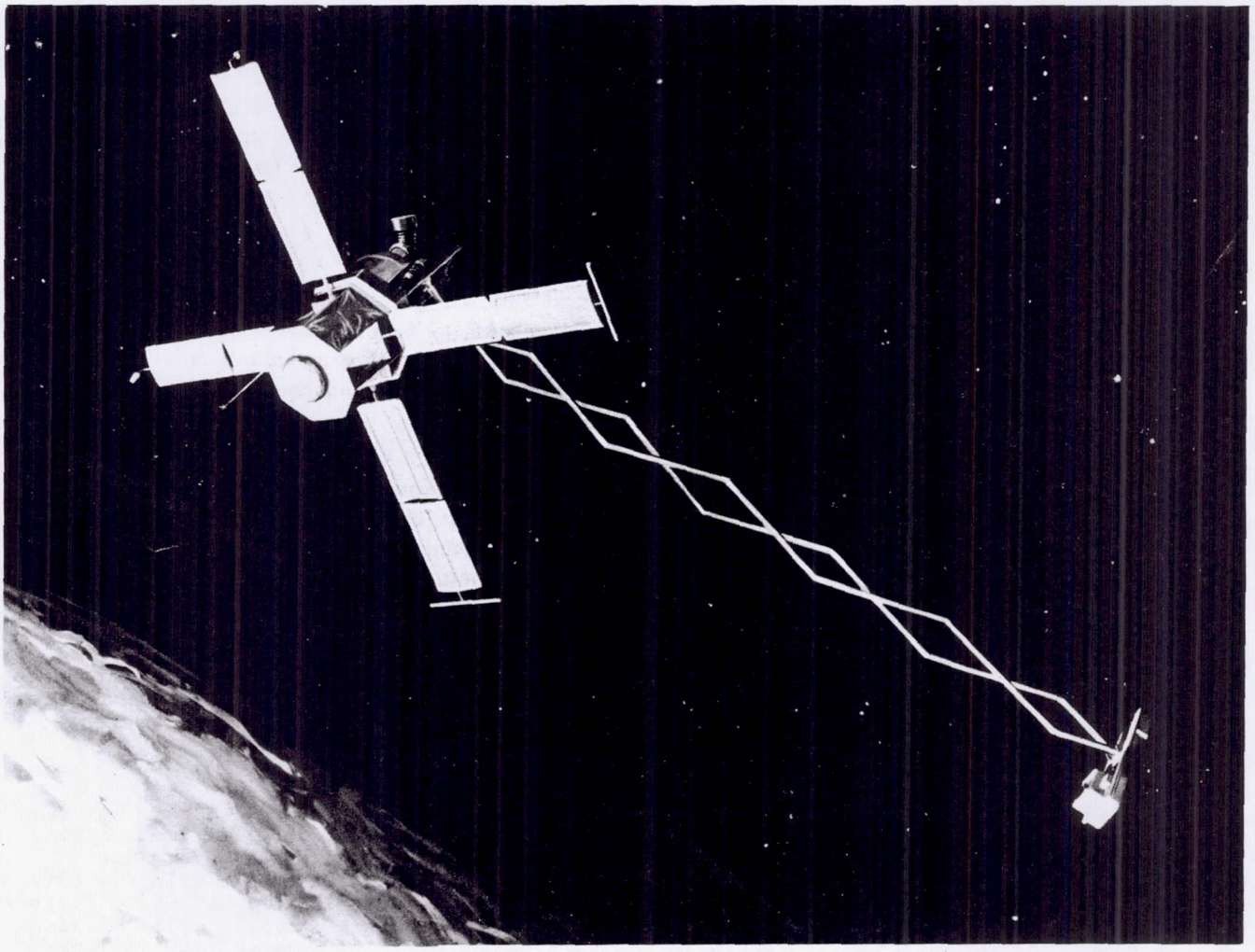
Goddard Space Flight Center--Robert E. Smylie, Acting Director; John H. Boeckel, Acting Director, Project Management, Gilbert W. Ousley, Magsat Project Manager; Dr. Robert A. Langel, Magsat Project Scientist; John H. Berbert, Data Manager; Charles E. White, Deputy Project Manager/Technical; Martin D. Menton, Deputy Project Manager/Resources, Norman J. Piterski, Mission Operations Manager; Donald L. Margolies, Spacecraft Manager; John J. O'Brien, Instrument Manager; Dr. Mario H. Acuna, Vector Magnetometer Instrument Scientist; Dr. Winfield H. Farthing, Scalar Magnetometer Technical Officer; Robert G. Sanford, Mission Support Manager; Richard H. Sclafford, Network Support Manager.

Kennedy Space Center--Richard G. Smith, Director; George F. Page, Director, Expendable Launch Vehicles; H.R. Van Goey, Manager, Western Operations Office; Gene E. Schlimmer, Manager, Magsat Spacecraft Operations.

Langley Research Center--Donald P. Hearth, Director, Lee R. Foster, Manager, Scout Project Office; Larry R. Tant, Magsat Coordinator Scout Project Office; Donald E. Forney, Manager, Langley Mission Support Field Office.

Experiment	Experiment Personnel	Affiliation
Scalar Magnetometer	PI R.A. Langel	NASA-GSFC
	OI M.H. Acuna	NASA-GSFC
Vector Magnetometer	PI R.A. Langel	NASA-GSFC
	OI M.H. Acuna	NASA-GSFC

Magnetic Field Satellite (MAGSAT), was the first spacecraft designed specifically to measure the near-Earth magnetic field and crustal conditions.



SATCOM 3/RCA-C

Launch Vehicle—Delta 3914, 8 feet in diameter, (without attached solids), 116 feet high; thrust at liftoff: 421,000 pounds.

Spacecraft Description—Box-shaped main structure with dimensions of 47 x 64 x 46 inches. Two 61-inch by 89-inch solar paddles extended in winglike fashion and provided about 770 watts of electrical power. A four-reflector antenna assembly was mounted atop the main body. The three-axis stabilized spacecraft weighed about 1,800 pounds at launch, and about 1,000 pounds in orbit, after the onboard apogee kick motor had expended its propellant.

Project Objectives—Expand the capacity of RCA's domestic satellite communications system.

Spacecraft Payload—Communications system included 24 independent 36-MHz transponders operating in the 6 to 4 GHz frequency range. The four-reflector antenna system provided 12 vertically polarized and 12 horizontally polarized antennas, fed by six feedhorns.

Project Results—Satcom 3/RCA-C was launched by a Delta vehicle from Cape Canaveral on December 6, 1979, and achieved its elliptical transfer orbit. Communications with the spacecraft ceased shortly after the firing of Satcom's apogee kick motor to boost the satellite to geosynchronous orbit.

Major Participants—Systems management, RCA Global Communications, Inc.; Spacecraft prime contractor, RCA AstroElectronics; launch vehicle management, NASA Goddard; launch operations, NASA Kennedy Space Center; launch vehicle prime contractor, McDonnell Douglas.

NASA Headquarters

Glynn S. Lunney, Acting Associate Administrator for Space Transportation System, Operations; Joseph B. Mahon, Director of Expendable Launch Vehicle Systems; Peter T. Eaton, Manager, Delta Program.

Goddard Space Flight Center

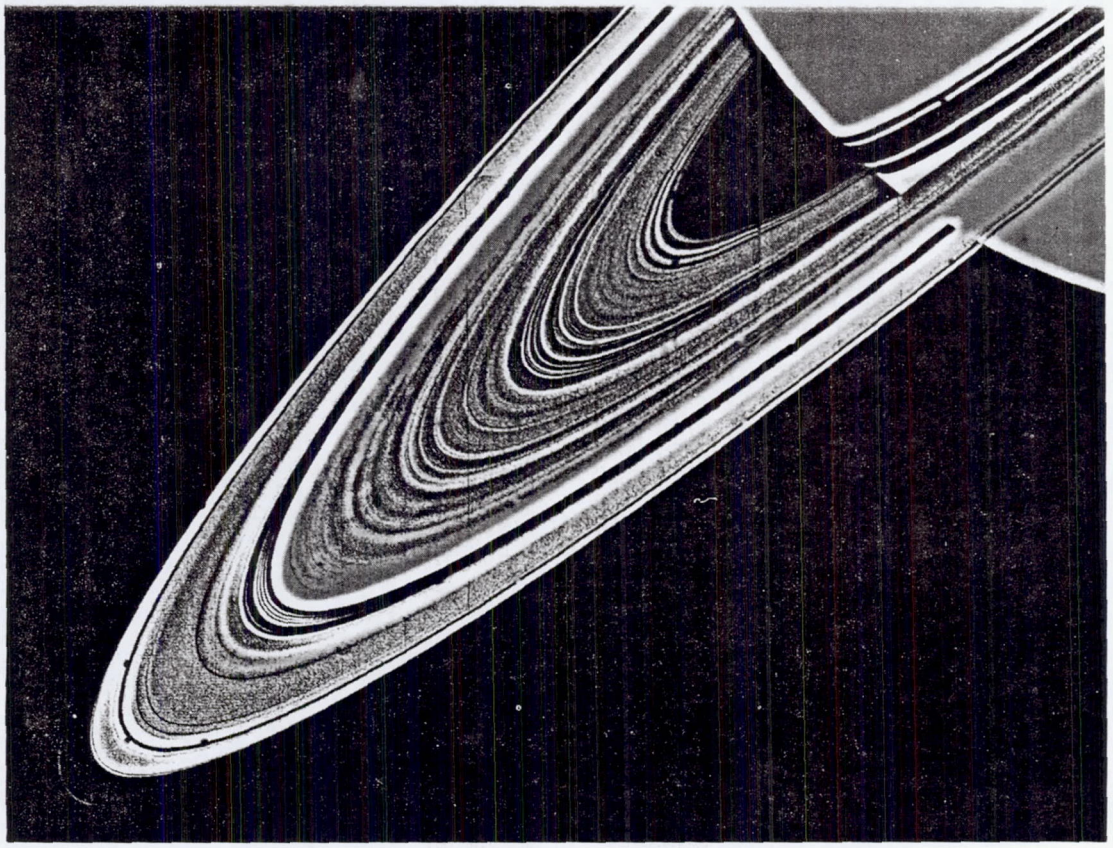
Robert E. Smylie, Acting Director; John Boeckel, Acting Director, Project Management; Paul Mowatt, Associate Director for Project Management; David W. Grimes, Delta Project Manager; William R. Russell, Deputy Delta Project Manager, Technical; Robert Goss, Manager, Delta Mission Analysis and Integration; Philip Frustace, RCA SATCOM-C Mission Integration Manager; William Hawkins, Mission Operations and Network Support Manager; Ray Mazur, Mission Support.

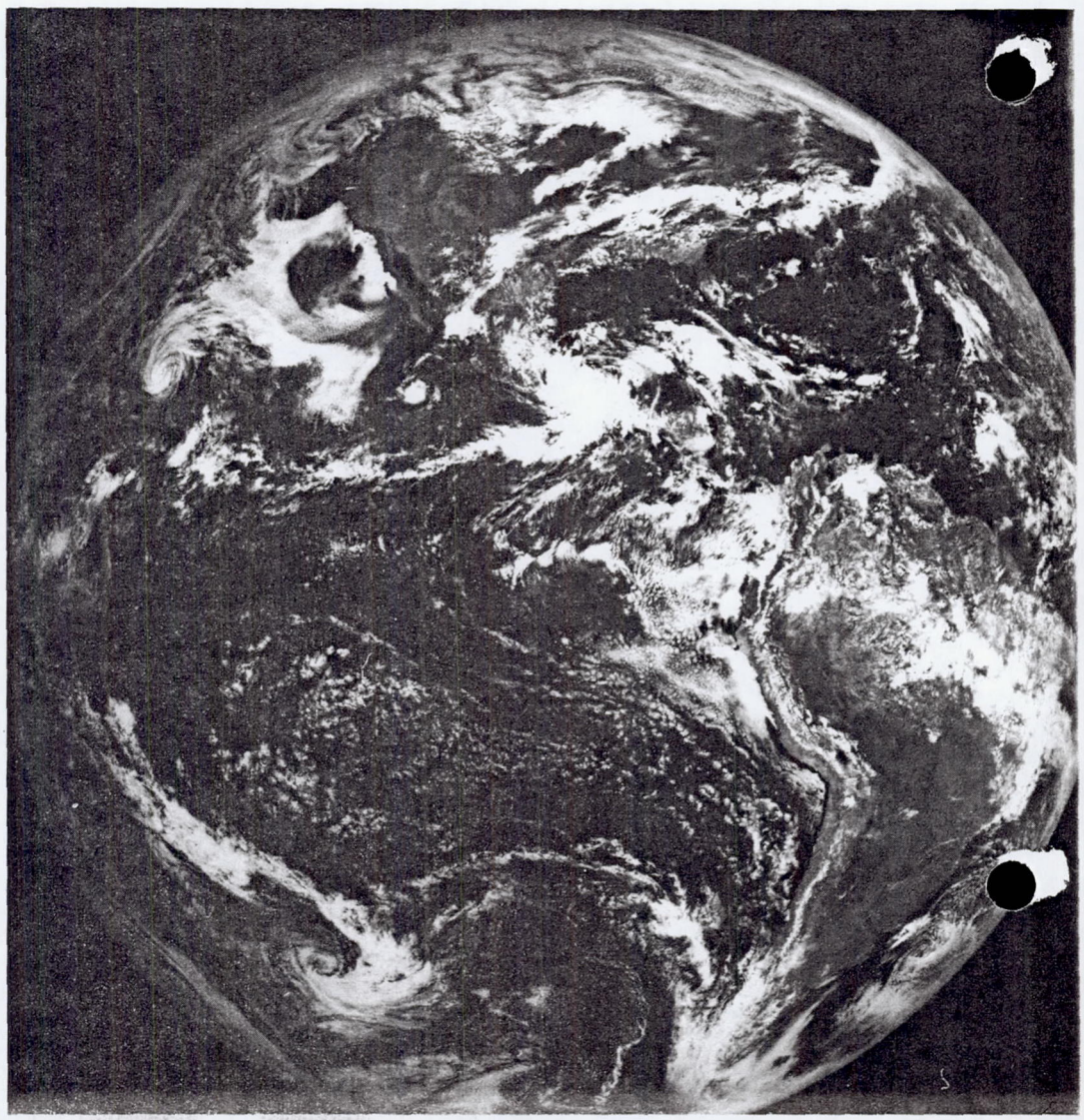
Kennedy Space Center

Richard G. Smith, Director; Charles D. Gay, Director, Deployable Payloads Operations; D.C. Sheppard, Chief, Automated Payloads Division; Wayne L. McCall, Chief, Delta Operations Division; David C. Bragdon, Spacecraft Coordinator.

RCA American Communications, Inc.

Andrew Inglis, President; John Christopher, Vice President of Technical Operations; Peter Plush, Manager, Major Programs and Technical Operations Services; Joseph Schwarze, Manager, Space Systems; William Palme, Manager, Major Programs, Launch Vehicle Integration; Joseph Elko, Manager, Spacecraft Engineering.





1980 provided new and startling views of the Earth, the Sun, and Saturn. Above: a computer assembled mosaic of Saturn's rings taken by Voyager 1 on November 9, at a range of 8 million kilometers (5 million miles). The 14th satellite of Saturn, discovered by Voyager 1, is seen upper left just inside the narrow F-ring. Right: GOES-4 spacecraft took this picture of the Earth. Image shows South America on the right; the United States can be seen above the center. Over extreme southern Mexico and Honduras is a cyclonic cloud pattern.

This was the 52nd launch of an Atlas Centaur; NASA was reimbursed for all additive costs of the Atlas Centaur and launch services by the Department of Defense under provisions of a launch services agreement.

Major Participants — The FLTSATCOM program was managed by the Naval Electronic Systems Command. The Air Force Space Division was responsible for production, launch vehicle/spacecraft integration, and tracking and data acquisition. NASA's Lewis Research Center, Cleveland, Ohio, had management responsibility for the Atlas Centaur development and operation. NASA's Kennedy Space Center, Fla., was assigned vehicle checkout and launch responsibility; launch vehicle prime contractor was General Dynamics Corporation.

NASA Headquarters

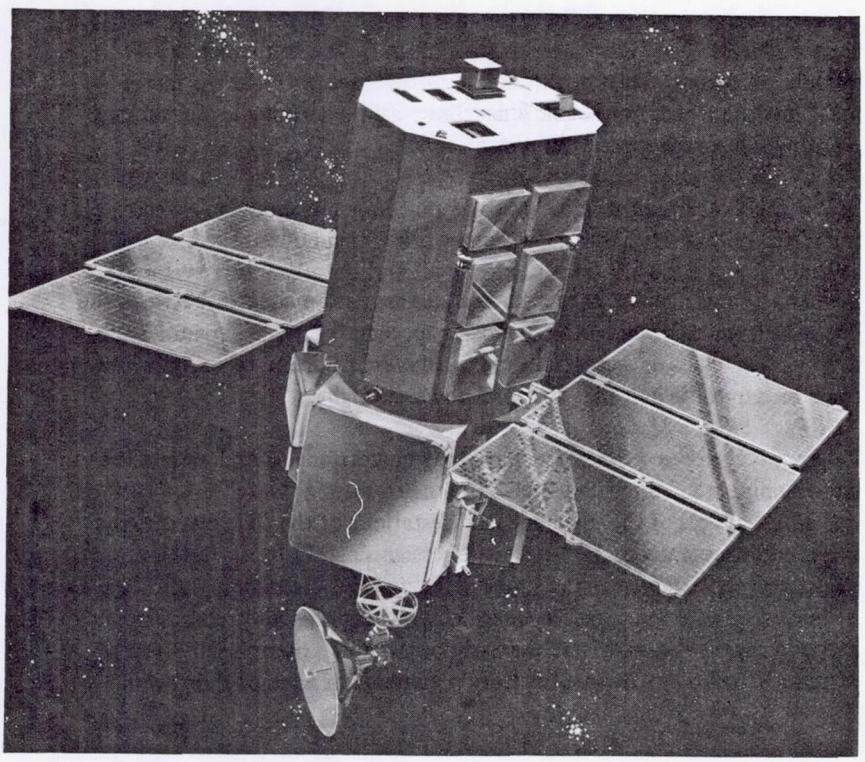
Glynn S. Lunney, Acting Associate Administrator for Space Transportation Systems Operations; Joseph B. Mahon, Director, Expendable Launch Vehicles; F.R. Schmidt, Manager, Atlas Centaur Launch Vehicle.

Lewis Research Center

Dr. John F. McCarthy, Jr., Director; Dr. Seymour C. Himmel, Associate Director; Lawrence J. Ross, Director, Launch Vehicles; J.E. Patterson, Chief, Vehicles Engineering Division; C.B. Wentworth, Chief, Program Integration Division; Kenneth A. Adams, FLTSATCOM Mission Project Engineer; Frank L. Manning, FLTSATCOM Vehicle Engineer.

Kennedy Space Center

Richard G. Smith, Director; George F. Page, Director, Cargo Operations; John Gossett, Chief, Centaur Operations Division; Barry Olton, Spacecraft Coordinator



Solar Maximum Mission spacecraft carrying seven scientific instruments, provided scientists with observations of solar flares–violent eruptions on the Sun's surface–over a wide band of wavelengths in the ultraviolet, X-ray, and gamma-ray regions of the spectrum.

SOLAR MAXIMUM MISSION (SMM)

Launch Vehicle – The launch vehicle consisted of a thrust-augmented Delta 3910, 35.5 (116 ft) including the spacecraft shroud. Liftoff weight was 190,000 kg (418,000 lbs), and lift-off thrust was 462,714 lbs, including the startup thrust of five of the nine solid motor strap-ons (the remaining strap-ons were ignited at 64 seconds after lift-off).

The first stage booster was an extended long-tank Thor powered by the Rocketdyne RS-27 engine system which used hydrazine (RP-1) and liquid oxygen propellants. Pitch and yaw steering was provided by gimballing the main engine. The vernier engines provided roll control during powered flight control during coast.

The second stage was powered by the TRW TR-201 liquid bipropellant engine using $N_2 0_4$ as the oxidizer and aerozene-50 as the fuel. Pitch and yaw steering during powered flight was provided by gimballing the engine. Roll steering during powered flight and all steering during coast were provided by a GN_2 cold gas system.

The guidance and control system of the vehicle was located on top of the second stage. The strapdown delta inertial guidance system (DIGS) provided guidance and control for the total vehicle from liftoff through attitude orientation and separation of the SMM. The system was composed of a digital computer and the inertial measurement units (IMU).

First and second stage telemetry systems were similar, both combining the use of pulse duration and frequency modulation. Critical vehicle functions were monitored to provide data for determining which components, if any, were not functioning properly during ascent.

Spacecraft Description – The solar maximum mission spacecraft was approximately 4 m (13 ft.) in length, 2.3 m (7 ft.) in diameter, and modular in design. The upper portion of the spacecraft was the instrument module which housed all solar observation instruments and the fine pointing sun sensor system for aiming control.

Below the instrument module was the multimission modular spacecraft (MMS), a 1.5 m (5 ft.) triangular framework which housed the essential attitude control, power, communications, and data handling systems. Two fixed solar paddles were attached to a transition adaptor between the upper instrument module and the lower spacecraft bus. The paddles supplied power to the spacecraft during the daylight portion of orbits while three rechargeable batteries supplied power at night.

Program Objectives – Scientists have long been trying to understand the many complex phenomena which combine to form a "flare". A wealth of individual studies of the different manifestations of the flare event exists and these investigations have contributed significantly to the development of a conceptual picture of the processes which may be taking place. There is, however, still considerable uncertainty as to the interrelationship between these processes. Are the early brightenings occasionally seen in extreme ultraviolet wavelengths truly precursors of a major flare event?

Where does the flare trigger occur? Is there sufficient energy in the accelerated particle beam to account for all the subsequent radiative and particle emissions that are observed? Does chromospheric evaporation explain the subsequent particle emission? And what configuration of active region fields actually allows particles to escape? The resolution of these questions, and many more, requires temporally and spatially coordinated observations of a flare over the wide range of its complex phenomena.

The Solar Maximum Mission (SMM) was designed to provide these observations. The spacecraft was launched in early 1980 near the peak of maximum solar activity and carried a payload of six instruments specifically selected to study the major short wavelength and coronal manifestations of flares.

The payload was to obtain data on the storage and release of flare plasma, and mass ejection. Complementary ground-based observations of the flares' radio and optical emissions were to be made as part of the SMM guest investigator program and coordinated in situ measurements of the flare particle emissions to be obtained by the International Sun-Earth Explorer C satellite. By organizing such a comprehensive program at a time in the solar cycle when activity was to be at a peak, it would be possible to study all aspects of a wide variety of different types of active phenomena including active regions, flares, and transient events, and hence to answer may questions surrounding these phenomena.

In addition to those instruments designed for flare observation, SMM carried a solar constant monitor to accurately measure the total radiative output of the sun during the period of SMM operation.

Spacecraft Payload – The observatory was approximately 4 m in length and encapsulated into a circular envelope 2.3 m in diameter. The total observatory weight was about 2315 kg. The construction was modular providing the capability for in-orbit change out of the spacecraft subsystem modules. The upper portion of the spacecraft, 2.3 m, comprised the instrument module which housed all the solar payload instruments as well as the fine pointing sun sensor system, for pointing control. These were mounted on the same instrument support plate (ISP). Below the instrument module, and separated from it by a transition adaptor, the multimission modular spacecraft which was a triangular framework supporting three modules – each about 1.2 X 1.2 X 0.5m in dimension which housed the essential components of the three spacecraft subsystems: attitude control, power, and communication and data handling. The transition adaptor supported the two fixed solar paddles, which supplied between 3000 and 1500 watts of power. The spacecraft structure also supported two other components: the signal conditioning and control unit, and the high gain telemetry antenna system.

The electrical power subsystem supplied power at an unregulated 28 (±7) Vdc negative ground, and the power switching unit distributed power to the instrument module through three separate supply buses: quiet power,

pulse load, and heater power. The total observatory power was supplied during orbit days by the solar array system; power during orbit nights and eclipses were drawn from three rechargeable, nickel-cadmium 20 A-hr batteries.

The attitude control subsystem (ACS) stabilized the observatory, pointed it to a target on or near the solar disk, and performed pre-planned, slew maneuvers for repointing or generating scan patterns. The prime attitude sensor was the redundant pointing sensor on the ISP with a resolution of 0.1 arc sec and a calibrated accuracy of better than 5.0 arc sec. The control module of the MMS had an optical bench on which were mounted a high performance inertial reference unit containing three 2-axis gyroscopes with an angular resolution capability of 0.02 arc sec, and a pair of 2-axis, fixed-head star trackers with electronic scanning capability over an 8 X 8 arc min field of view and a calibrated accuracy better than one arc min. During normal operation, the data from these sensors was processed by the attitude determination and control software in the onboard computer (OBC), and the control commands were sent to reaction wheels in the ACS module to control observatory pointing to within ±5 arc sec (±3 arc sec for 5 minutes of time) in each of two orthogonal axes (pitch and yaw) in solar coordinates. The total pointing range was approximately +25 arc min from Sun center. The roll about the line-of-sight to the Sun was controlled to within ±0.1 arc min of an inertial orientation defined such that the projections of the observatory pitch and yaw axes coincide with the north-south and east-west directions, respectively, on the solar disk. To support the scientific observing program, regular roll changes up to ±90 degrees from this nominal roll orientation were planned.

The spacecraft carried the following scientific instruments:

- Gamma ray spectrometer – to measure the intensity, energy, and Doppler shift of narrow gamma ray radiation lines and the intensity of extremely broadened lines. The goal was to study ways in which high-energy particles are produced in solar flares.
- Hard X-ray spectrometer – to help determine the role that energetic electrons play in the solar flare phenomenon.
- Hard X-ray imaging spectrometer – to image the Sun in hard X-rays and to provide information about the position, extension, and spectrum of the hard X-ray bursts in flares.
- Soft X-ray polychromator – to investigate solar activity that produces solar plasma temperatures in the 1.5 to 50 million degree range. Studies solar plasma density and temperature.
- Ultraviolet spectrometer and polarimeter – to study the ultraviolet radiation from the solar atmosphere, particularly from active regions, flares, prominences, and the active corona, and to study the quiet Sun.

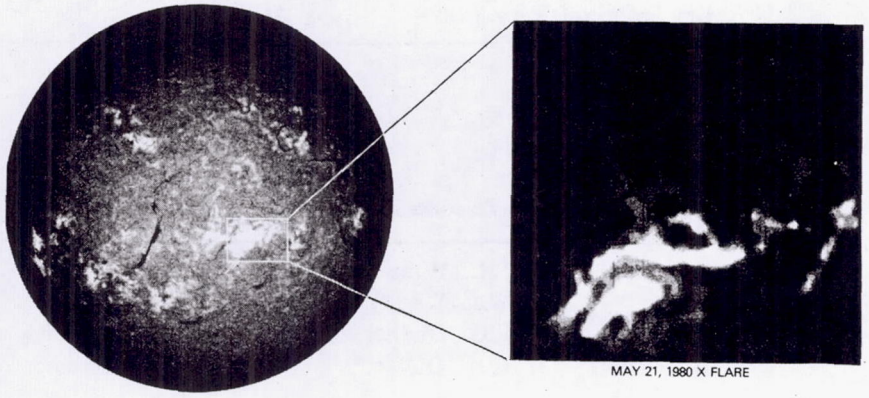
- High altitude observatory coronagraph/polarimeter – to return imagery of the Sun's corona in parts of the visible spectrum as part of an investigation of coronal disturbances created by solar flares.

- Solar constant monitoring package – to monitor the output of the Sun over most of the spectrum and over the entire solar surface.

The satellite was the first solar satellite designed to study a specific solar phenomenon such as flares, using a coordinated set of instruments that measure many different flares in different wavelengths of light.

The communication and data handling subsystem received commands uplinked from ground, allowed tracking, stored on-board data in tape recorders, transmitted data to ground via telemetry, and contained the on-board computer (OBC) and its interfaces. This system was compatible with both the Space Tracking & Data Network (STDN) and the future NASA-standard Tracking & Data Relay Satellite System. The command rate was 2 kbps (1 kbps for OBC dump data 512 kpbs for tape recorders playback data, and an optical 256 kbps for tape recorder playback or instrument real-time data). The telemetry data were arranged in 8 bit words, 128 words in a minor frame and 128 minor frames to a major frame.

Test Results – The SMM was launched from the Eastern Test Range (ETR) on February 14, 1980. Subsequently the six science investigations on SMM performed a detailed study of a specific set of solar phenomena: the impulsive, energetic events known as solar flares, and the active regions which are the sites of flares, sunspots, and other manifestations of solar activity. One instrument also measured the total output of radiation from the Sun.



The Sun, as it appeared during the X flare on May 21, 1980. The flare's brightness overwhelms all other solar features. The inset shows the ultraviolet emission from the flare as recorded on NASA's Solar Maximum Mission.

The satellite was a three-axis inertially stabilized platform providing precise pointing to any region on the solar disk. The spacecraft orbit was circular, inclined 28.5 degrees to the equator, with an altitude of 575 kilometers. Mission support was provided by the Goddard Space Flight Center (GSFC) Space Tracking & Data Network, with the Operational Control Center located at GSFC.

Major Participants – The solar maximum mission was managed for NASA's Office of Space Science, Washington, D.C., and by the Goddard Space Flight Center, Greenbelt, Md. Michael E. McDonald was program manager and Dr. Eric Chipman was program scientist. At Goddard, project manager was Peter Burr, and Kenneth J. Frost project scientist.

NASA Headquarters

Dr. Thomas A. Mutch, Associate Administrator for Space Science; Andrew J. Stofan, Deputy Associate Administrator for Space Science; Dr. Adrienne F. Timothy, Assistant Associate Administrator for Space Science; Dr. Harold Glaser, Director, Solar Terrestrial Division; Dr. Eric G. Chipman, Program Scientist; Dr. Glynn S. Lunney, Acting Associate Administrator for Space Transportation Systems Operations; Joseph B. Mahon, Director, Expendable Launch Vehicles Systems; Peter T. Eaton, Manager, Delta Program; Dr. William C. Schneider, Associate Administrator for Space Tracking and Data Systems; Charles A. Taylor, Director, Network Operations and Communications Programs.

Goddard Space Flight Center

A. Thomas Young, Director; Frank J. Ceppolina, Multimission Spacecraft Project Manager; John H. Boeckel, Acting Director Project Management Directorate; Joseph Purcell, Deputy Director, Project Management Directorate; Robert C. Baumann. Associate Director, Project Management Directorate; Paul A. Mowatt, Associate Director for Projects, Project Management Directorate; Henry K. Arneson, Assistant Director for Resources, Project Management Directorate; Paul G. Marcotte, Assistant Director for Engineering, Project Management Directorate.

Kennedy Space Center

Richard G. Smith, Director; Charles D. Gay, Director, Deployable Payloads Operations; D.C. Sheppard, Chief, Automated Payloads Division; Wayne L. McCall, Chief, Delta Operations Division; John Dunn, Spacecraft Coordinator.

Key Spacecraft Personnel		Affiliation
PS	K.J. Frost	NASA-GSFC
SC	J.D. Bohlin	NASA-Headquarters
MG	M.E. McDonald	NASA-Headquarters
PM	P.T. Burr	NASA-GSFC

Experiments	Key Personnel		Affiliation
Coronagraph/ Polarimeter	PI	L.L. House	High Altitude Observatory
	OI	W.J. Wagner	High Altitude Observatory
	OI	E.G. Hildner	High Altitude Observatory
	OI	G.A. Dulk	University of Colorado

Experiments	Key Personnel			Affiliation
Ultraviolet Spectrometer/ Polarimeter	PI	E.	Tandberg-Hanssen	NASA-MFSC
	OI	R.G.	Athay	High Altitude Observatory
	OI	J.M.	Beckers	Sacremento Peak Observatory
	OI	J.C.	Brandt	NASA-GSFC
	OI	E.C.	Bruner, Jr.	Lockheed Palo Alto
	OI	R.D.	Chapman	NASA-GSFC
	OI	B.E.	Woodgate	NASA-GSFC
Soft X-Ray Polychromator	PI	L.W.	Acton	Lockheed Palo Alto
	OP	A.H.	Gabriel	Appleton Laboratory
	OP	J.L.	Culhane	University College London
	OI	R.C.	Catura	Lockheed Palo Alto
	OI	J.H.	Parkinson	University College London
	OI	C.G.	Rapley	University College London
	OI	B.B.	Jones	Appleton Laboratory
	OI	C.	Jordan	Oxford University
	OI	C.J.	Wolfson	Lockheed Palo Alto
	OI	B.C.	Fawcett	Appleton Laboratory
Hard X-Ray Imaging Spectrometer	PI	C.	De Jager	University of Utrecht
	OI	H.F.	Van Beek	Space Research Laboratory
	OI	A.P.	Willmore	University of Birmingham
Hard X-Ray Burst Spectrometer	PI	K.J.	Frost	NASA-GSFC
	OI	L.E.	Orwig	NASA-GSFC
	OI	B.R.	Dennis	NASA-GSFC
	OI	T.L.	Cline	NASA-GSFC
	OI	U.D.	Desai	NASA-GSFC
Gamma-Ray Spectromtr (GRE)	PI	E.L.	Chupp	University of New Hampshire
	PI	D.J.	Forrest	University of New Hampshire
	OI	K.	Pinkau	MPI-Extraterrestrial Physics
	OI	C.	Reppin	MPI-Extraterrestrial Physics
	OI	E.	Rieger	MPI-Extraterrestrial Physics
	OI	W.N.	Johnson	US Naval Research Laboratory
	OI	R.L.	Kinzer	US Naval Research Laboratory
	OI	J.D.	Kurfess	US Naval Research Laboratory
	OI	G.H.	Share	US Naval Research Laboratory
	OI	A.S.	Jacobson	NASA-JPL
Active Cavity Irradium Monitor	PI	R.C.	Willson	NASA-JPL

NOAA-7

Launch Vehicle – The launch vehicle consisted of a mission-modified Atlas-F supplied by the Air Force. The launch vehicle's overall length, including the spacecraft fairing, was 28.1 meters (92.25 ft). The maximum diameter was 3 m (10 ft.). It was manufactured by the General Dynamics Corp.

The Atlas-F was powered by liquid oxygen (LOX) and a liquid hydrocarbon fuel. The booster system consisted of two fixed thrust engines which were gimballed to provide pitch, yaw, and roll control from lift-off through booster engine cut-off (BECO). The sustainer engine, also fixed thrust and was gimballed and provided pitch and yaw control to the vehicle from just before booster engine cut-off until sustainer cutoff (SECO). Following booster staging, two vernier engines provided roll control. After SECO the vernier engines provided fine trajectory corrections.

Spacecraft Description – The NOAA-7 satellite was an integrated spacecraft system designed to provide for, and control injection into the required orbit after separation from the Atlas-F launch vehicle.

The spacecraft, including the apogee kick motor (AKM), in the launch configuration was 371 cm (146 in.) high and 188 cm (74 in.) in diameter and weighed nominally 1,405 kg (3,095 lb.). On-orbit, with the AKM and reaction-control equipment expendables consumed, the satellite had a nominal weight of 723 kg (1,590 lb.).

The solid rocket apogee kick motor, which was to perform the orbit injection maneuver, was an integral part of the NOAA-B spacecraft. It contained 664 kg (1,464 lbs) of propellant which burned to depletion in five seconds, leaving the empty motor assembly case, weighing 50.4 kg (111 lbs), in orbit with the spacecraft. During the motor burn the spacecraft was stablized by nitrogen and hydrazine thrusters.

The spacecraft carried the following subsystems: structure-thermal, power, attitude determination, control, and communications and data handling.

Program Objectives – NOAA-7 was the third of eight TIROS-N series operational meteorological polar orbiting spacecraft. The purpose of these satellites was to make measurements of temperature and humidity in the Earth's atmosphere, surface temperature, surface and cloud cover, water-ice-moisture boundaries, and proton and electron flux near the Earth. They have the capability of receiving, processing, and retransmitting data from free-floating balloons, buoys, and remote automatic stations distributed around the globe and can also track stations which are in motion.

NOAA-7 objectives include collection of environmental data for use in the National Operational Environmental Satellite System (NOESS). Specific objectives included providing improved methods of obtaining quantitative environmental data and improved data handling capabilities through:

- High resolution, day and night cloud cover observations on a local and global scale;
- High resolution observations of sea surface temperatures;
- Improved observations of vertical temperatures and water vapor profiles in the troposphere and lower stratosphere on a global basis.
- Observations of vertical temperature profiles in the middle and upper stratosphere on a global basis;
- Operational flight of a high-capacity data collection/relay and platform location system;
- Observations of electron and proton flux densities and total particle energy densities in the near-Earth space environment.

Spacecraft Payload – One of the NOAA objectives for the TIROS-N series was to provide timely day and night sea surface temperature, ice, snow, and cloud information to diverse users. The instrument used to obtain this data was the advanced very high resolution radiometer (AVHRR).

The spacecraft also carried a data collection and platform location subsystem. This subsystem provided for the receipt, processing, and storage of data (temperature, pressure, altitude, etc.) from fixed and moving platforms (e.g., free-floating balloons and buoys) and for the location of the moving platforms for later transmission to a central processing facility.

In addition its Tiros operational vertical sounder (TOVS) system was to be used to determine the vertical temperature profile of the atmosphere from the Earth's surface to near the top of the atmosphere (1 mb) and moisture vapor content profile from the surface to the tropopause. It was to compute these profiles globally to an accuracy of 1 degree C (temperature) and 20 percent moisture vapor content (10 percent desired) on a grid spacing at the Earth's surface of 400 km (248 mi.) or less, even in the presence of clouds.

Its space environment monitor was to provide continuous measurement of proton alpha and electron flux activity near the Earth. This instrument was an extension of the solar proton monitor (SPM) previously flown on ITOS satellites. The instrument package additionally provided for measurement of alpha and electron flux, spectrum and total energy disposition into the Earth's upper atmosphere.

The data handling subsystem consisted of four primary components; the Tiros Information Processor (TIP), the manipulated information rate processor (MIR), digital tape recorders, and the Cross Strap Unit (CSU). All data available for transmission to the ground were processed by some or all of the components.

Test Results – NOAA-7 was launched from the Western Space and Missile Center in California May 29, 1980. It was expected to remain in orbit only about six months. Difficulties developed during the launch caused the satellite to go into a highly elliptical (1028km apogee and 250km perigee, rather than a planned circular orbit. During the launch one booster engine in the Atlas-F launch vehicle developed only 75 percent thrust.

Major Participants –

Key Spacecraft Personnel		Affiliation
PS	A. Arking	NASA GSFC
MG	M.L. Garbacz	NASA Headquarters
PM	G.A. Branchflower	NASA GSFC

Experiments	Key Personnel		Affiliation
Advance Very High Research Radiometer	PI	Ness Staff	NOAA-NESS
	CO	W.E. Shenk	NASA-GSFC
Operational Vertical Sounder	PI	Ness Staff	NOAA-NESS
Data Collection System	PI	Ness Staff	NOAA-NESS
Space Environmental Monitor	PI	D.J. Williams	NOAA-ERL
	OI	H.H. Sauer	NOAA-ERL
	OI	C.O. Bostrom	Applied Physics Lab

NOAA/NESS

David S. Johnson, Assistant Administrator, Satellites, NOAA; Diana Josephson, Deputy Assistant Administrator; E. Larry Heacock, Director of Systems Development; J. Gordon Vaeth, Director, Satellite Operations; Arthur Schwalb, Chief, Oceanic and Atmospheric Satellite Systems; Dario Galoppo, Payload Coordinator, Thomas J. Karras, Manager, Satellite Operations Control Center; Gary K. Davis, NOAA-C Operations Readiness Team Leader; Everitt W. Kendall, Manager, Command and Data Acquisition Station (Wallops Island); William C. Callicott, Chief, Information Processing Division; Donald C. Winner, Chief, Satellite Services Division.

NASA Headquarters

Dr. Anthony J. Calio, Associate Administrator for Space and Terrestrial Applications; Samuel W. Keller, Deputy Associate Administrator for Space and Terrestrial Applications; Dr. Lawrence R. Greenwood, Director, Environmental Observations Division; W.P. Bishop, Deputy Director, Environmental Observations Division; Ray J. Arnold, Manager, Operational Meteorological Satellite Program; Tom W. Perry, Deputy Program Manager, Operational Meteorological Satellites; S.G. Tilford, Chief of Atmospheric Processes Branch; J.S. Theon, Program Scientist, Global Weather Research; Dr. Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joseph B. Mahon, Director, Expendable Launch Vehicles Program; Jay A. Salmanson, Program Manager, Atlas Launch Vehicle; Robert E. Smylie, Associate Administrator for Tracking and Data Systems.

Goddard Space Flight Center

A. Thomas Young, Director; William C. Keathley, Director, Flight Projects Directorate; G.W. Longanecker, Project Manager; Dr. William N. Redisch, Deputy Project Manager; John A. Underwood, Deputy Project Manager, Resources; William M. Peacock, Spacecraft Manager; Lawrence T. Draper, Instrument Manager; John F. Corrigan, Launch Vehicle Manager; David K. Coolidge, Mission Operations Manager.

Launch Vehicle – The launch vehicle consisted of a three-stage, inertially-guided Delta launch vehicle, utilizing a Thor booster with nine solid motors for thrust augmentation, a TR-201 second stage, and TE-364-4 third stage was used to inject the spacecraft into a transfer orbit from which its apogee boost motor could place the satellite into a synchronous orbit. The spacecraft was temporarily stationed at 90 degrees W longitude for performance of the Visible infrared spin-sedu radiometric atmospheric sounder (VAS) demonstration experiment.

Spacecraft Description – The spacecraft was 85 inches (215 centimeters) in diameter, and its overall height was 138 inches (350 centimeters). The weight of GOES-D was 1840 pounds (836 kilograms) when launched by the Delta 3914 booster, and 874 pounds (397 kilograms) at beginning of mission life in orbit after firing and ejecting its self-contained solid motor.

The spinning, drum-shaped base of the spacecraft housed the earth, sun, and X-ray sensors, the energetic particle monitor, and axial and radial thrusters for attitude control. Solar panels were bonded on the entire exterior surface of the drum sides, and a magnetometer was mounted on a boom situated at the edge of the drum. Contained within, but protruding from the base at the center was the primary instrument, the VAS, and its sunshade.

The S-band high gain antenna, the UHF antenna, and the S-band omni-directional antenna were mounted atop the VAS housing and mechanically despun by an electric motor so as to point at the earth while the base was spinning for stability.

Test Results – Launched September 9, 1980 from Eastern Test Range, Orbital elements: 35801km apogee, 35,774km perigee.

Program Objectives – First U.S. satellite capable of near-continuous monitoring of atmospheric water vapor and temperatures. Data collected must be used to analyze storms and the short-lived weather phenomena they produce. Weather forecasters and other scientist were to use the data the satellite records to study severe storms and storm-spawned phenomena such as hail, flash floods, and tornadoes.

Spacecraft Payload – The following instrumentation packages:

- The visible infrared spin-scan radiometric atmospheric sounder (VAS) a new instrument incorporating the functions of the visible infrared spin scan radiometer (VISSR) flown on GOES 1, 2, and 3 with capability, atmospheric sounding.

- The space environmental monitor (SEM) included a magnetometer, a solar X-ray telescope, and an energetic particle monitor, designed to provide direct quantitative measurements of the important effects of solar activity for use in real-time solar forecasting and subsequent research. This subsystem, which detects

Experiments		Key Personnel	Affiliation
VISSR Atmospheric Sounder (VAS)	PI	Ness Staff	NOAA-NESS
	OI	W.E. Shenk	NASA-GSFC
Solar Energetic Particles	PI	D.J. Williams	NOAA-ERL
	OI	H.H. Sauer	NOAA-ERL
Solar X-Ray Monitor	PI	D.J. Williams	NOAA-ERL
	OI	R.F. Donnelly	NOAA-ERL
Biaxial Fluxgate Magnetometer	PI	D.J. Williams	NOAA-ERL
	OI	J.N. Barfield	Southwest Research Institute
Meteorological Data Collection System	PI	Ness Staff	NOAA-NESS

NOAA

David S. Johnson, Assistant Administrator, Designate, for Satellites, NOAA; Clifford A. Spohn, Deputy Director, National Earth Satellite Service (NESS); George H. Ludwig, Director of Operations; E. Larry Heacock, Director of Systems Integration; Edward W. Mowle, Chief, Geostationary System Group; Edward W. Bisone, Spacecraft Manager; Jack Urion, Financial Representative; James C. Fischer, Payload Coordinator; Sheila Frye, Goddard Liaison Adminstrative Assistant; Faris T. Kahwajy, Acting Chief, Satellite Operations Division; Thomas J. Karras, Manager, Satellite Operational Control Center; Gary K. Davis, GOES-D Operations Readiness Team Leader; Everitt W. Kendall, Manager, Command and Data Acquisition Station (Wallops Island); William C. Callicott, Chief, Information Processing Division; Donald C. Winner, Chief, Satellite Services Division.

NASA Headquarters

Stanley I. Weiss, Associate Administrator, Office of Space Transportation Operations; Robert E. Smylie, Associate Administrator, Office of Space Tracking and Data Acquisition; Joseph B. Mahon, Director, Expendable Launch Vehicle Program; Peter Eaton, Manager, Delta Launch Vehicles.

Goddard Space Flight Center

A. Thomas Young, Director; John H. McElroy, Deputy Director; William C. Keathley, Director of Projects; Paul A. Mowatt, Associate Director for GOES and Delta; David W. Grimes, Delta Project Manager, William Russell, Deputy Delta Project Manager, Technical; Frank Lawrence, Delta Mission Integration Manager, Robert Pickard, Project Manager, GOES-D; Richard Wirth, Deputy Project Manager, Technical; August Wessels, Deputy Project Manager, Resources; W.H. Farthing, Science Manager; Arthur C. Clarke, Spacecraft Manager, John Lahzun, Assistant Spacecraft Manager; William C. Bryant, Mission Operations Manager; Ralph Bannin, Network Operations Manager, Kermit Blaney, Network Support Manager; Michael Prokopchak, Mission Support Manager; Larry Rouzer, Instrument Manager.

Kennedy Space Center

Richard G. Smith, Director; Tom Walton, Director of Cargo Operations; Charles Gay, Director, Deployable Payloads Operations; D.C. Sheppard, Chief, Automated Payloads Division; Wayne McCall, Chief, Delta Operations Division.

FLTSATCOM-D

Launch Vehicle – The launch vehicle consisted of an Atlas Centaur, standing approximately 39.9 m (131 ft.) high, an Atlas SIV-3D booster, and Centaur D-1AR second stage. The Atlas booster developed 1,920 kilonewtons (431-300 lbs.) of thrust at liftoff using two 822,920-newton (185,000-lbs.) thrust booster engines, one 266,890-N (60,000-lb.) thrust sustainer engine and two vernier engines developing 2,890 N (650 lb.) thrust each. The two RL-10 engines on Centaur produced a total of 133,450 N (30,000 lb.) thrust. Both the Atlas and the Centaur were 3m (10 ft.) in diameter. Lift-off weight including spacecraft: 148,173 kg (326,665 lbs.).

Spacecraft Description – The FLTSATCOM spacecraft consisted of two major hexagonal elements, a payload module and a spacecraft module. A majority of the electronic equipment was mounted on 12 panels that enclose the payload and spacecraft modules.

The spacecraft module contained the Earth sensors, apogee kick motor, attitude and velocity control, telemetry tracking and command (TT&C), electrical power distribution, and the solar array.

The solar array was folded around the spacecraft module prior to its final position in orbit where it was deployed by spring loaded hinges. It was exposed to sunlight in both the deployed and folded positions.

During the transfer orbit operations and through apogee kick motor burn, the spacecraft was spin stabilized. After apogee kick motor burn, the spacecraft was despun, solar arrays and the UHF antenna was deployed, and the Sun and Earth acquired. In normal mode on orbit operations, the spacecraft was pointed at the center of the Earth by Earth sensors, roll/yaw jets, and a reaction wheel. (The solar array is usually normal to the orbit plane and is rotated at a uniform rate to point at the Sun.) Rotation was achieved by a clocked drive with command correction available. A redundant monopropellant hydrazine thruster system was provided for spacecraft control and velocity maneuvers. A solid propellant apogee kick motor injected the spacecraft into a circular, near-synchronous orbit.

Solar arrays and batteries interfaced with a command electrical power bus which distributed primary power to the subsystem equipment converters.

Program Objectives – FLTSATCOM-D was an advanced Earth satellite designed to provide extensive communication capability for the USAF and USN. The satellite was placed in a synchronous, near equatorial orbit. The spacecraft provided 23 UHF and one SHF communication channels. Services are: Fleet broadcast, channel 1; Fleet relay, channels 2 through 10; Air Force narrowband, channels 11 through 22; and a DOD wideband channel 23; and an additional Telemetry Tracking and Command (TT&C) S-band channel.

Spacecraft Payload – The payload module, which was fastened to the six corners of the spacecraft module, contained the UHFand X-band communications equipment and antennas. The UHF transmit antenna was made of ribs and mesh that opened like an umbrella, and the receive antenna was a separate, deployable helix antenna. The spacecraft provided 23 UHF and one SHF communications channels including: Fleet broadcast, channel 1; Fleet relay, channels 2 through 10; Air Force narrowband, channels 11 through 22; and a DOD wideband, channel 23.

Test Results – FLTSATCOM-D spacecraft was successfully launched into a synchronous transfer orbit by the Atlas-Centaur AC-57 from the ETR on October 30, 1980. The transfer orbit parameters were as follows:

	Actual	Nominal
Inclination (degrees)	26.3542	26.3558
Eccentricity	0.73158	0.7322
Apogee (km)	35972	35963
Perigee (km)	166.7	167.1

The spacecraft apogee kick motor was successfully fired at fifth apogee on November 1, 1980, injecting the FLTSATCOM spacecraft into the described synchronous orbit. All spacecraft systems were turned on and were operating as planned.

Major Participants – The FLTSATCOM program was a project of USAF, Space Communications Systems; Space & Missile Systems Organization. The Atlas Centaur prelaunch and launch operations at ETR were performed by Convair Division of General Dynamics under contractual direction from the NASA Lewis Research Center. The FLTSATCOM spacecraft prelaunch and launch operations were performed by Thompson Ramo Woolridge, Inc. Operational and technical direction over prelaunch operations of the launch vehicle and launch countdown operations of the launch vehicle/spacecraft combination were administered by the Kennedy Space Center/Expendable Vehicle Directorate.

NASA Headquarters

Dr. Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joseph B. Mahon, Director, Expendable Launch Vehicles; F.R. Schmidt, Manager, Atlas Centaur Launch Vehicle.

Lewis Research Center

Dr. John F. McCarthy, Jr., Director; Dr. John Klineberg, Associate Director; Lawrence J. Ross, Director, Space Directorate; J.E. Patterson, Chief, Vehicles Engineering Division; S.V. Szabo, Jr., Deputy Chief, Launch Vehicles Division; Kenneth A. Adams, FLTSATCOM Mission Project Engineer; Kenneth W. Baud, FLTSATCOM Vehicle Engineer.

Kennedy Space Center

Richard G. Smith, Director; Thomas S. Walton, Director, Cargo Operations; Charles D. Gay, Director, Deployable Payloads Operations; John Gossett, Chief, Centaur Operations; Barry Olton, Spacecraft Coordinator.

SATELLITE BUSINESS SYSTEMS (SBS-A)

Launch Vehicle – The launch vehicle consisted of a thrust-augmented Delta 3910. Overall the Delta 3910 35.5m (116 ft.) including the spacecraft shroud. Liftoff weight was 190,630 kg (420,269 lb) and liftoff thrust was 2,058,245 newtons (462,714 lb) including the startup thrust of five of the nine solid motor strapons (the remaining strapons were ignited at 64 seconds after liftoff).

The first stage booster was an extended long-tank Thor powered by the Rocketdyne RS-27 engine system which used Hydrazine (RP-1) and liquid oxygen popellants. Pitch and yaw steering was provided by gimballing the main engine. The vernier engines provided roll control during powered flight and control during coast.

The second stage was powered by a TRW TR-201 liquid bipropellant engine using N_2O_4 as the oxidizer and aerozene-50 as the fuel. Pitch and yaw steering during powered flights were provided by gimballing the engine. Roll steering during powered flight and all steering during coast was provided by a GN_2 cold gas system.

This was the first use of the McDonnell Douglas developed payload assist module (PAM-D), which placed the spacecraft into a synchronous transfer orbit. The spacecraft apogee kick motor was fired at transfer orbit apogee to circularize its orbit at geosynchronous altitude of roughly 19,300NM above the equator at approximately 106 degrees W longitude.

Spacecraft Description – A spin-stabilized satellite 216 centimeters (7 ft 1 in.) in diameter with a stowed height at launch of 282 cm (9 ft. 3 in.). After deployment in its geosynchronous orbit at about 35,880 km (22,300 mi) above the Earth, the telescoping solar panel cylinder was extended and the communications antenna raised giving the satellite an overall height of 660 cm (21 ft. 8 in.).

Program Objectives – Provided integrated, all-digital, interference-free transmission of telephone, computer, electronic mail, and video teleconferencing to business and industrial clients. The SBS domestic satellite system provided fully switched private networks to businesses, government agencies, and other organizations with large, varied communications requirements.

Spacecraft Payload – A spin-stabilized satellite that utilized two concentric cylindrical solar panels. When the outer panel was deployed downward, the combination provide a 914 watt end-of-life power required by the communication task. The power system had improved solar cells, providing 20 milliwatts per sq cm were used. Two nickel-cadmium batteries provided full power service during eclipse operation.

The satellite repeater was organized into ten channels, each 43 MHz wide. Each channel used a 20 watt multicollector traveling wave tube. With the antenna gain developed by the single, large shapped beam reflector, a signal strength of over 43.7 dBw was provided in the primary eastern

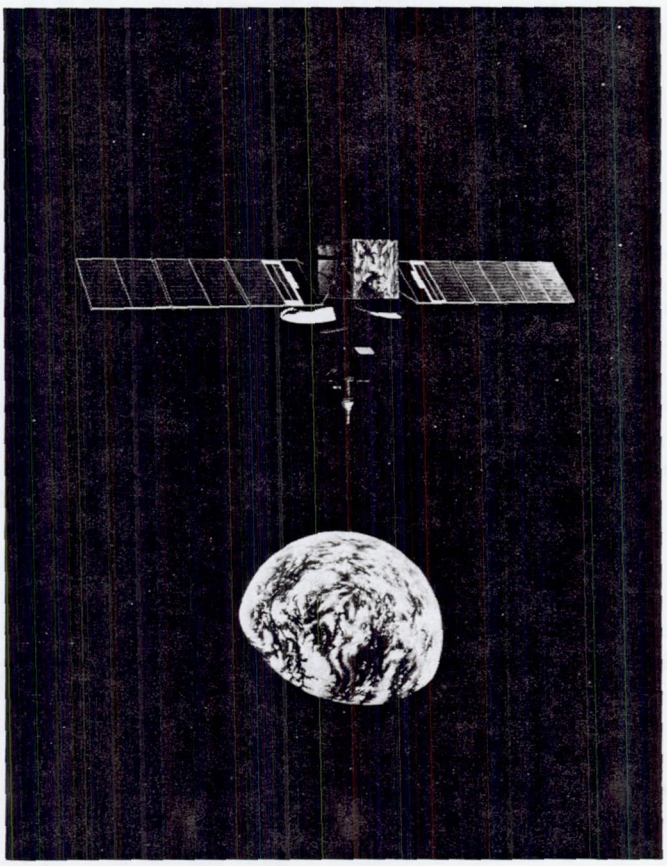
coverage zone. The redundant receivers used solid-state FET microwave integrated circuit techniques, and provided weighted beam receive sensitivities of G/T = 2-1/2 to +2.0 dB/°K over the most densely populated regions of the U.S.

Test Results – Launched from the ETR on November 15, 1980. Orbital elements were 35,800 km apogee and 35,771 km perigee. Became operational March 1981.

Major Participants – The launch support for this mission was provided by NASA, on a reimbursable basis, to SBS, a consortium of IBM, Comsat General, and AETNA Insurance, at a fixed price of $22.0M. Customers included the Westinghouse Electric Corporation, the Travelers Companies, Boeing Computer Services and the General Motors Corporation.

Delta was managed for the NASA Office of Space Transportation Operations by the Goddard Space Flight Center. Launch operations management was the responsibility of Kennedy Space Center's Deployable Payloads Operations Division. The McDonnell Douglas Astronautics Corp., Huntington Beach, CA, was the Delta prime contractor for the vehicle and launch services.

An artist's conception of INTELSAT V satellite in synchronous orbit 36,000 km (22,300 miles) above the Earth.



INTELSAT V (F-2)

Launch Vehicle – The Atlas Centaur (AC-54), standing approximately 39.9 m (131 ft.) high, consisted of an Atlas SIV-3D booster and Centaur D-1AR second stage. The Atlas booster develops 1,920 kilonewtons (431,300 lb.) of thrust at liftoff using two 822,920-newton (185,000-lb.) thrust booster engines, one 266,890-N (60,000-lb.) thrust sustainer engine and two vernier engines developing 2,890 N (650 lb.) thrust each. The two RL-10 engines on Centaur produce a total of 133,450 N (30,000 lb.) thrust. Both the Atlas and the Centaur are 3 m (10 ft.) in diameter.

The Atlas Centaur (AC-54) launch vehicle placed the Intelsat V into a highly elliptical orbit. From this orbit, at apogee, a solid propellant rocket motor attached to the satellite was fired to circularize the orbit at geosynchronous altitudes over the equator for communications between North America and Europe.

Spacecraft Description – The satellite weighed 1,928 kg (4,251 lbs.) at launch. Having almost double the communications capability of earlier satellites in the Intelsat series it had a height of 6.4 m (21.0 ft.), a width, fully deployed, of 6.8 m (22.25 ft.) and a main body of 1.66 by 2.01 by 1.77 m (5.4 by 6.6 by 5.8 ft.).

Program Objectives – The Intelsat global satellite system comprised two elements: the space segment consisting of satellites owned by Intelsat positioned over the Atlantic, Indian, and Pacific Ocean regions; and the ground segments, consisting of Earth stations owned by telecommunications entities in the countries in which they are located. The ground segment of the global system consisted of 295 communications antennas at 242 Earth station sites in 129 countries and territories.

The combined system of satellites and Earth stations provided more than 800 Earth station-to-Earth station communications pathways.

Spacecraft Payload – A modularly constructed three-axis body stabilized with Sun and Earth sensors and momentum wheel. Its wing-like, Sun-oriented solar array panels produced a total of 1,241 watts of electrical power. These communications characteristics were as follows:

- Capacity average 12,000 simultaneous two-way telephone circuits and two television channels. It utilized both the 14/11 GHz frequency band and the 6/4 GHz frequency band. It carried six communications antennas – two global coverage horns, two hemispherical/zone offset-fed reflectors and two offset-fed spot beam reflectors.

Test Results – The satellite was launched from Cape Kennedy, on December 6, 1980. Its orbital elements were as follows:

Inclination (deg)	23.75
Eccentricity	.73217
Apogee (km)	35,950
Perigee (km)	166.8

The apogee kick motor was fired on December 8 placing the satellite into near geosynchronous orbit. After initial positioning at 15 degrees East longitude for preliminary testing, the satellite was to be moved to be on-station at 338.5 degrees East longitude by mid-1981.

Major Participants – Intelsat V satellite was built by the Ford Aerospace and Communications Corp., Palo Alto, Calif., using system components developed by the following:

- Aerospatiale (France) initiated the structural design that formed the main member of the spacecraft modular design construction. It supplied the main body structure thermal analysis and control.
- GEC-Marconi (United Kingdom) produced the 11 GHz beacon transmitter used for Earth station antenna tracking.
- Messerschmitt-Bolkow-Blohm (Federal Republic of Germany) designed and produced the satellite's control subsystem and the solar array.
- Mitsubishi Electric Corporation (Japan) was responsible for both the 6 GHz and the 4 GHz Earth coverage antennas. It also manufactured the power control electronics and the telemetry and command digital units.
- Selenia (Italy) designed and built the six telemetry, command, and ranging antennas, two 11 GHz beacon antennas and two 14/11 GHz spot beam antennas. Also the command receiver and telemetry transmitter which combine to form a ranging transponder for determination of the spacecraft position in transfer orbit.
- Thomson-CSF (France) built the ten 10w, 11 GHz traveling wave tubes.
- GDC launch vehicle prime contractor.

NASA Headquarters

Dr. Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joseph B. Mahon, Director, Expendable Launch Vehicles; and F. R. Schmidt, Manager, Atlas Centaur Launch Vehicle.

Lewis Research Center

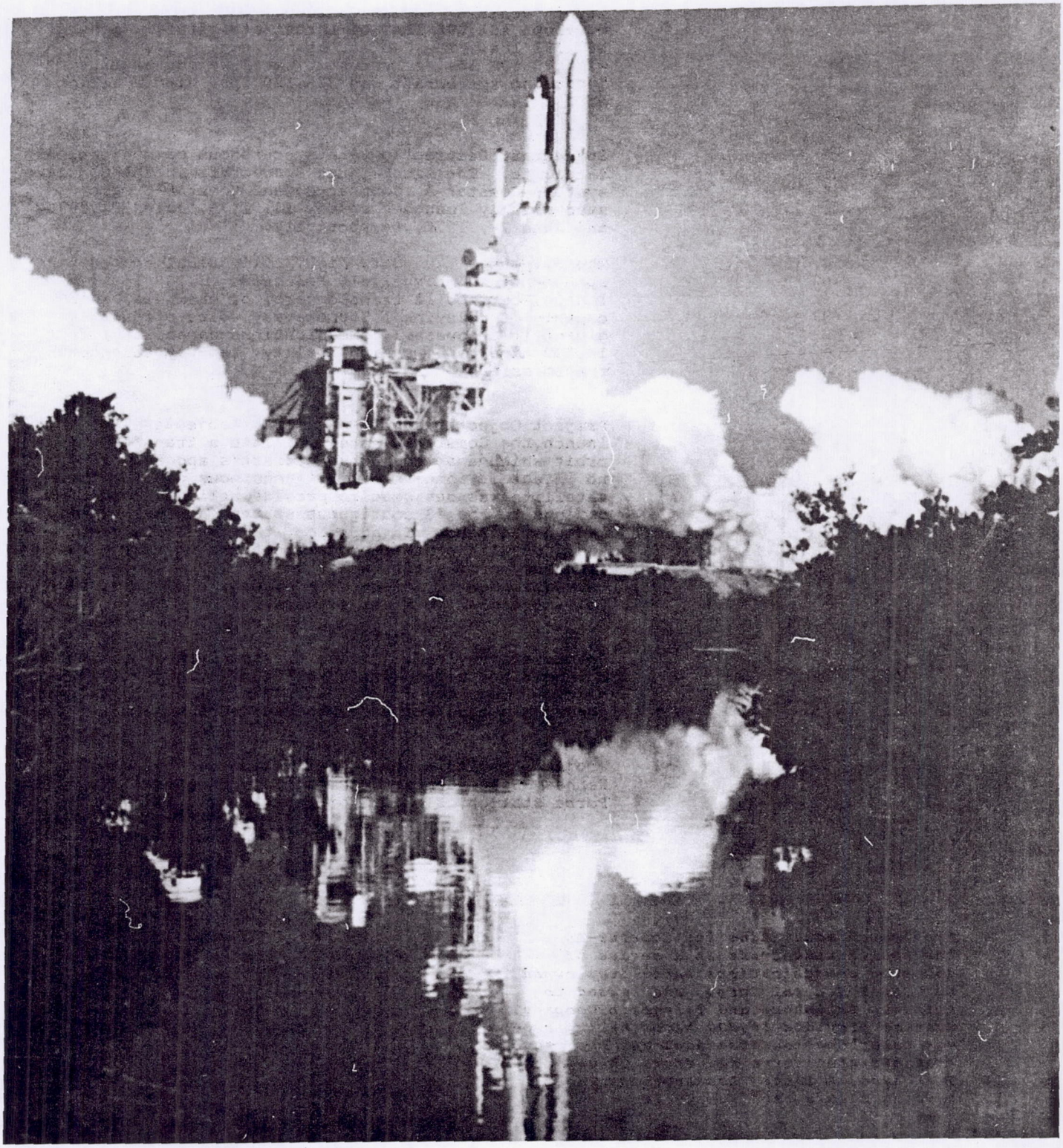
Dr. John F. McCarthy, Jr., Director; Dr. John Klineberg, Associate Director; Lawrence J. Ross, Director, Space Directorate; J. E. Patterson, Chief, Vehicles Engineering Division; S. V. Szabo, Jr., Deputy Chief, Launch Vehicles Division; and Richard E. Orzechowski, INTELSAT Mission Project Engineer.

Kennedy Space Center

Richard G. Smith, Director; Thomas S. Walton, Director, Cargo Operations; Charles D. Gay, Director, Deployable Payloads Operations; John Gossett, Chief, Centaur Operations; and Lawrence F. Kruse, Spacecraft Coordinator.

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1981



STS-1 thunders past the top of the service tower on its way into orbit as the successful maiden flight of the space shuttle concept begins.

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COMSTAR-D

Launch Vehicle - Atlas-Centaur. The Atlas booster develops 431,000 lbs. of thrust at liftoff weighing 287,391 lbs. The Centaur stage weighed 39,151 lbs. with 29,500 lbs. of thrust. Total weight at liftoff including spacecraft was 326,120 lbs. with a height of 133 ft.

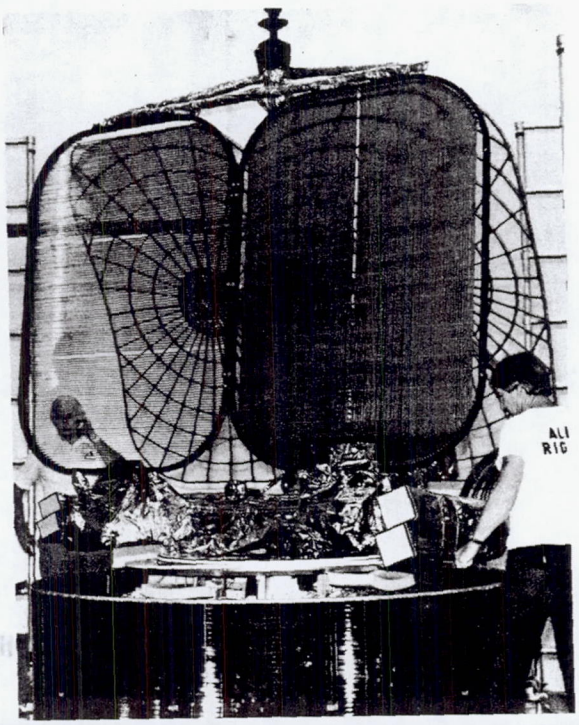
Spacecraft Description - A synchronous communications satellite. The first three spacecraft in the Comstar system--Comstar-A, Comstar-B, and Comstar-C were successfully launched on May 13, 1976, July 22, 1976, and June 29, 1978, respectively.

The 6.1-meter (20 foot) high, cylindrical-shaped spacecraft weighing 1,516 kilograms (3,342 lbs.) at launch, carried 12 transponders, or channels, each capable of relaying 1,500 one-way voice circuits, giving it an overall communications capability of 18,000 simultaneous high quality, two-way telephone transmissions.

Project Objectives - It was NASA's objective to launch the Comstar-D satellite into a transfer orbit which enabled the spacecraft's apogee motor to inject it into an earth-synchronous orbit. The satellite was designed to provide reliable communications to the 48 contiguous states, Alaska, Hawaii, and Puerto Rico. In addition, the satellite was equipped with centimeter wave beacons to test higher frequency propagation at 19 and 28 GHz. These tests were designed to measure the adverse effects of rainfall on signal in these frequencies.

Spacecraft Payload - Twelve transponders operating on a receiving frequency of 5925-6425 MHz and a transmitting frequency of 3700-4200 MHz. A single transponder has a capacity of about 1,200 channels.

Project Results - Successfully launched by John F. Kennedy Space Center from the Cape Canaveral Air Force Station, Florida, on February 21, 1981.



Pre-launch activities for Comstar-D, the fourth spacecraft in a series of domestic communications satellites owned by COMSAT General Corp., and leased to American Telephone and Telegraph Company. Comstar provides 18,000 high quality two-way telephone conversations and has ground stations that serve New York, Chicago, San Francisco, Atlanta, Los Angeles, Tampa, Hawaii, Alaska, and Puerto Rico.

Major Participants -

NASA HEADQUARTERS

Dr. Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joseph B. Mahon, Director, Expendable Launch Vehicles Program; and F. R. Schmidt, Manager, Atlas Centaur.

LEWIS RESEARCH CENTER

Dr. J. F. McCarthy, Director; Lawrence J. Ross, Director of Space; and Richard E. Orezechowski, Comstar Mission Project Engineer.

KENNEDY SPACE CENTER

Richard G. Smith, Director; Thomas S. Walton, Director, Cargo Operations; Charles D. Gay, Director, Deployable Payloads Operations; John Gossett, Chief, Centaur Operations; D. C. Sheppard, Chief, Automated Payloads Division; and Art Sawyer, Spacecraft Coordinator.

COMSAT GENERAL/COMSTAR

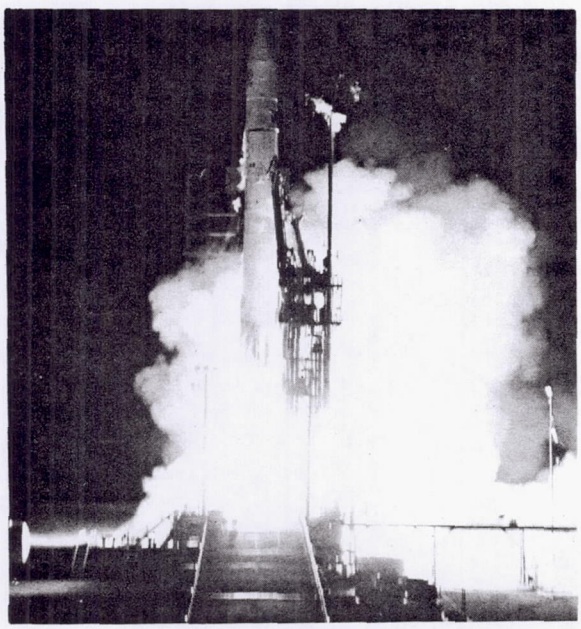
C. Guthrie, Manager, Comstar Program; L. H. Westerlund, Manager, Engineering Space Segment Development and Control.

HUGHES AIRCRAFT COMPANY

H. Leap, Comstar D-4 Project Manager.

CONTRACTORS

General Dynamics/Convair, San Diego, Calif., Atlas Centaur launch vehicle; Honeywell Aerospace Division, St. Petersburg, Fla., Centaur guidance inertial measurement group; Pratt and Whitney Aircraft Group, West Palm Beach, Fla., Centaur RL-10 engines; Teledyne Industries, Inc., Northridge, Calif., digital computer unit/PCM telemetry; and Rocketdyne Division, Rockwell International Corporation, Canoga Park, Calif., MA-5 propulsion systems.



Comstar-D communications satellite, atop its Atlas Centaur launch vehicle, lifted off from Launch Complex 36, Cape Canaveral Air Force Station, bound for its geosynchronous orbital position as fourth in the series of domestic communications satellites owned by COMSAT General Corporation.

STS-1
Space Transportation System
Space Shuttle Columbia

Program Overview - The Space Shuttle is composed of the Orbiter, an External Tank that contains the propellant used by the Orbiter's three main engines, and two Solid Rocket Boosters. The Orbiter and boosters were reusable; the External Tank is expended on each launch.

A Space Shuttle mission begins with installation of the mission payload into the Orbiter cargo bay. The payload is checked out, serviced and activated after reaching orbit. The Solid Rocket Boosters and the Orbiter main engines are fired together at liftoff. The two Solid Rocket Boosters are jettisoned after burnout--about 44 kilometers (27.5 miles) high--and recovered by means of a parachute recovery system. A homing device on each booster guides recovery craft to it for towing back to shore. The boosters are then refurbished, refueled, and made ready for another Shuttle flight. The Orbiter main engines continue to burn until the Orbiter is just short of orbital velocity, at which time the engines are shut down and the External Tank is jettisoned. During its plunge through the atmosphere, the tank tumbles, breaks up, and falls into a predetermined ocean area--the Indian Ocean for launches from Kennedy Space Center (KSC) in Florida and the South Pacific Ocean for launches from Vandenberg Air Force Base (VAFB) in California.

An orbital maneuvering system is available to attain the desired orbit and to make any subsequent maneuvers that may be needed during the mission. The crew then begins their payload operations by performing a multitude of assigned tasks, depending upon the purpose of the mission, such as retrieving satellites from Earth orbit, servicing orbiting satellites, conducting experiments in space that cannot be duplicated on Earth, and studying the Earth and deep space from their unique vantage point high above the atmosphere.

After orbital operations are completed, normally about 7 days, deorbiting maneuvers are initiated. The Orbiter begins to reenter the Earth's atmosphere at a high angle of attack. During reentry, portions of the Orbiter exterior reaches temperatures up to 1,260 degrees Celsius (2,300 degrees Fahrenheit). The Orbiter levels into horizontal flight at low attitude for an unpowered aircraft-type approach and landing at a speed of about 335 kilometers per hour (208 miles per hour).

The primary Shuttle landing facilities are KSC and VAFB, with several alternate landing sites available for contingencies.

After landing, the Orbiter is towed to ground facilities where any returned payloads are removed. Orbiter refurbishment operations make it ready for another mission in about 2 weeks.

Electrical power for the Space Shuttle and the payloads is generated by three fuel cells that use cryogenically stored hydrogen and oxygen. The fuel cells are in the forward end of the Orbiter midfuselage. During peak and average power conditions, all three fuel cells are used. The quantities of fuel (hydrogen and oxygen) normally carried by the Orbiter are enough to generate about 1,530 kilowatt hours of energy. The amount includes 50 kilowatt hours of energy required by a typical payload for a 7 day mission. If additional power is needed, separate fuel kits may be carried aboard, each kit supplying fuel enough for an additional 840 kilowatt hours of energy.

A byproduct of the chemical conversion of hydrogen and oxygen to obtain electrical energy is the production of water. All the water for human consumption aboard the Shuttle is supplied from the byproducts of the fuel cells.

The Orbiter's communication antennas, about 20 of them, are flush mounted on the forward fuselage. Throughout the mission the Orbiter will provide direct voice, command, telemetry, and television communications with the ground crew, crewmen on EVA, and with detached payloads through its communications system and a network of ground stations and communications satellites.

Three main propulsion rocket engines used during launch are in the aft fuselage. Two orbital maneuvering rockets in external pods on the aft fuselage provide thrust for orbit insertion, orbit changes, rendezvous, and return to Earth. Reaction control thrusters in the two orbital maneuvering system pods and in a module in the nose section of the forward fuselage provide attitude control in space and precision velocity changes for the final phases of rendezvous and docking or orbit modification. The reaction control thrusters, in conjunction with the Orbiter's aerodynamic control surfaces, also provide attitude control of the Orbiter during reentry. The reaction control system controls the Orbiter at high altitude and velocity, and the aerodynamic control surfaces provide control of the Orbiter at speeds less than Mach 2.

The Orbiter, piloted by the crew but also equipped with an automatic landing system, will land at speeds of about 335 kph (208 mph), similar to current high performance aircraft.

The development of the Orbiter was the responsibility of JSC. Rockwell International Space Division was performing the design, development, and test of the Orbiter and its integration with other elements of the Shuttle. Subcontractors to Rockwell manufactured some of the major Orbiter subassemblies with final assembly performed at Rockwell's Palmdale, Calif., facilities. The Orbiter was transported, in its operational configuration, from its final assembly site to the launch site atop a modified Boeing 747 airplane. This same mode of transportation is used to transfer Orbiters between launch sites and to retrieve an Orbiter that has landed at an auxiliary landing field.

Launch Vehicle -

Space Shuttle Main Engine

The Space Shuttle Main Engine, designed to power the Space Shuttle, along with two Solid Rocket Boosters, was the most advanced liquid-fueled rocket engine ever built. With variable thrust permitting the engine thrust to be tailored to the mission needs, it operates effectively at both high and low altitudes. It had the highest thrust for its weight of any engine and could operate up to 7.5 hours of accumulated firing time before major maintenance or overhaul. The Main Engine was reusable for up to 55 separate Shuttle missions.

Three main engines were mounted on the Orbiter aft fuselage in a triangular pattern. The engines were so spaced that they could be gimballed during flight and in conjunction with the two Solid Rocket Boosters could be used to steer the Shuttle during flight as well as provide thrust for launch.

Fuel for the engines, liquid hydrogen and liquid oxygen, were carried in the External Tank, the largest element of the Space Shuttle. Fuel was supplied from the tank at a rate of about 171,396 liters (45,283 gallons) per minute of hydrogen and about 63,588 liters (16,800 gallons) per minute of oxygen.

Each engine had three primary levels of thrust or power--minimum, rated, and full power. Engine thrust, however, could be varied throughout the range from minimum to full power level depending upon mission needs. Most Shuttle flights will be launching at rated power level with each engine developing 2,090,560 Newtons (470,000 pounds) of thrust at altitude or 1,668,000 Newtons (375,000 pounds) at sea level. On some Shuttle flights where heavy payloads dictate an extra measure of power, up to full power level thrust could be commanded.

The development responsibility for the engines had been assigned to Marshall Space Flight Center (MSFC) in Huntsville, Ala., with the Rocketdyne Division of Rockwell International in Canoga Park, Calif., performing the design, production and test functions. The electronic controller was being developed by Honeywell, Inc., of Minneapolis, Minn., as a subcontractor to Rocketdyne.

Solid Rocket Boosters

Two Solid Rocket Boosters are used for each Space Shuttle flight to provide, along with the Orbiter main engines, the initial ascent thrust to lift the Shuttle with its payload from the launch pad to an altitude of about 44 kilometers (27.5 miles). Prior to launch, the entire Shuttle weight is supported by the two boosters.

The Solid Rocket Booster was made up of six subsystems: the solid rocket motor, structures, thrust vector control, separation, recovery and electrical and instrumentation subsystems. The overall length of the solid Rocket Booster is 45.5 meters (149.1 feet), and the diameter is 3.7 meters (12.2 feet).

The heart of each booster is the motor, the largest solid rocket motor ever flown and the first designed for reuse. It was made up of 11 segments joined together to make four loading segments filled with propellant at the manufacturer's site. The segmented design permitted ease of fabrication, handling, and transportation.

At burnout, the two Solid Rocket Boosters, separate from the External Tank by pyrotechnic (explosive) devices and move away from the Shuttle vehicle by eight separation motors, four housed in the forward nose frustum and four on the aft skirt. Each of the eight separation motors, fired at solid rocket motor burnout, develop a thrust of 97,856 N (22,000 lbs.) for a duration of a little more than one-half second, just enough to move the boosters away from the still accelerating Orbiter and External Tank.

Following separation and entry into the lower atmosphere at about 4,700 m (15,400 ft.), each booster is slowed by a pilot and a drogue parachute and finally by three main parachutes, each 31.7 m (104 feet) in diameter, to impact the water about 257.5 km (160 miles) downrange at a speed of about 95.5 km/or (60 mph), aft end first. At booster impact, the main parachutes will be disconnected and the direction finding beacons and lights will be actuated to guide recovery craft to the booster and the parachutes.

External Tank

The External Tank has two major roles in the Space Shuttle program--to contain and deliver quality propellants, liquid hydrogen and liquid oxygen to the engines and to serve as the structural backbone of the Space Shuttle during launch operations.

The External Tank was composed essentially of two tanks, a large hydrogen tank and a smaller oxygen tank, joined together to form one large propellant storage container 47 meters (154.2 feet) long and 8.4 meters (27.5 feet) in diameter.

The oxygen tank was the forward portion of the External Tank and, when loaded, contains 603,983 kilograms (1,331,555 pounds) of liquid oxygen. (As a comparison, the oxygen tank has 552 cubic meters or 19,500 cubic feet--more volume than that of a 186 sq. m or 2,000 sq. ft. house.)

The forward end of the oxygen tank curves to a point to reduce aerodynamic drag and also to provide lightning protection for the Shuttle vehicle once the Shuttle has cleared the launch pad.

The liquid hydrogen tank, aft of the oxygen tank, was about two-and-one-half times larger than the oxygen tank. In this tank is stored 101,503 kilograms (223,775 pounds) of cold liquid hydrogen (about minus 251 degrees C or minus 420 degrees F).

Near the end of the launch phase of a Shuttle mission when the Orbiter is just short of orbital velocity the main engines are cut off. About 10 seconds later, the External Tank is severed from its attachment to the Orbiter, playing a totally passive role in the separation sequence. Just prior to separation the External Tank tumbling system is activated, opening a valve and venting the oxygen tank through the nose cap. This causes the External Tank to pitch away from the Orbiter and begin to tumble at a rate that will assure the tank will break up upon reentry and fall within the designated ocean impact area.

The External Tank was manufactured, assembled, and given final acceptance testing at the Michoud Assembly Facility (MAF) in New Orleans, once used to build the first stages of the Saturn 1B and Saturn V launch vehicles for the Apollo and Skylab Programs. This location necessitated a reliable delivery-transportation capability to move the assembled tanks to either launch site, KSC or VAFB. The barge transportation system that was developed to deliver NASA's Saturn stages to KSC was used for the delivery of the External Tank. For shipment to VAFB a barge capable of hauling more than one External Tank will be used.

The development of the External Tank was the responsibility of MSFC with Martin Marietta Aerospace of Denver, Col., acting as prime contractor. The External Tank development phase calls for the design, development and test of three ground test tanks, one tank for each of the three ground test programs, and six development flight tanks.

Spacecraft Description -

Orbiter

The Orbiter carries the crew and the payloads for the Space Shuttle. About the size of a commercial DC-9 jet airliner, the Orbiter can deliver to orbit single or multiunit payloads up to 29,484 kilograms (65,000 pounds) in its huge 4.5 by 18 meter (15 by 60 foot) cargo bay, and bring back payloads weighing up to 14,515 kilograms (32,000 pounds).

The Orbiter's main structural elements, constructed primarily of aluminum, are the forward fuselage containing the crew module, the mid-fuselage including the payload bay doors, the aft-fuselage including the engine thrust structure, the wing, and the vertical tail.

The Orbiter's exterior is covered with thermal protective materials to protect the spacecraft from solar radiation and the extreme heat of atmospheric reentry.

Two types of reusable surface insulation, coated silica tiles and coated flexible sheets, cover the top and sides of the Orbiter. The tiles protect the Orbiter surfaces up to 649 degrees C (1,200 degrees F), and the flexible insulation protects the Orbiter up to 371 degrees C (700 degrees F). The coating on both types of insulation gives the Orbiter a nearly white color and has optical properties that reflect the solar radiation.

On the bottom of the Orbiter and on the leading edge of the tail, a high temperature reusable surface insulation, made of coated silica tiles, is used to protect the aluminum structure up to 1,260 degrees C (2,300 degrees F). The high temperature coating gives a glossy black appearance.

A reinforced carbon-carbon material is used for the nose cap and the wing leading edges where the temperatures will exceed 1,260 degrees C (2,300 degrees F) during reentry.

An important feature of the Orbiter is the crew and passenger accommodations. The Orbiter carries a crew of three and as many as four additional payload and technical personnel, occupying a two-level cabin within the crew module at the forward end of the vehicle. The cabin, a combination living, working, and storage area, is pressurized with a nitrogen/oxygen mixture to an atmospheric pressure of 10.1 Newtons per square centimeter (14.7 pounds per square inch) to simulate sea level conditions. (Prior U.S. manned space flight used an atmosphere at a pressure of 3.45 N/sq. cm. (5.00 lbs/sq. in.).

The upper section, or the flight deck, contains the controls and displays used to pilot, monitor, and control orbital maneuvering, atmospheric reentry, and landing phases of the mission and to control the mission payloads. Seating for the crew consists of the Commander, Pilot, and Mission Specialist, plus one payload specialist, is provided on this level. The Commander and Pilot are seated in the usual pilot/copilot arrangement with duplicate controls that permit the Orbiter to be piloted from either seat and returned to Earth by one crew member in an emergency.

Seating for three passengers/scientists and the habitability provisions are on the lower level or deck. The habitability provisions include a galley for food preparation (an oven and hot and cold water dispensers for the preparation of rehydratable freeze-dried foods) and an eating area, personal hygiene facilities for either male or female crew members/passengers, and sleeping accommodations.

The lower deck can be configured to provide three additional seats for a rescue mission by replacing the sleeping provisions with seats. Also to support a rescue mission, all Shuttle flights will carry extravehicular activity (EVA) provisions for two trained crewmen.

EVAs are planned on missions where access to the cargo bay and the payloads is necessary. The crewmen/payload specialists will exit the Orbiter through an airlock and hatch in the lower deck. It is also through this hatch that the scientists for the Spacelab missions can enter the pressurized Spacelab module to conduct the planned experiments.

The following describes the initial flight in this program:

Project Objectives - STS-1 and the three flights following were engineering test flights to prove out the Shuttle system in launch, orbital, and landing operations. As the first manned orbital flights, STS-1's flight profile had been designed to minimize structural and operational loads on the spacecraft and its boosters. Orbiter Columbia's cargo bay was bare for the first test flight except for a data collection and recording package called developmental flight instrumentation (DFI) and an aerodynamic coefficient identification package (ACIP).

The basic STS-1 flight objective was to demonstrate safe launch into orbit and return to landing of Columbia and its crew. Secondarily, the flight was to verify the combined performance of the entire Shuttle vehicle--Orbiter, solid rocket boosters, external tank--up through separation and retrieval of the spent solid rocket boosters. The flight also gathered data on the combined vehicle's aerodynamic and structural responses to the stress of launch. At mission end, similar data were gathered on Orbiter energy characteristics, such as crossrange steering capabilities, structural loads on entry, and performance of silica-tile thermal protection system.

A major portion of the flight and detailed test objectives were aimed toward evaluating Orbiter hardware systems and their operating computer software, and toward measuring the overall Orbiter thermal response while in orbit with payload doors opened and closed. Still other test objectives evaluated Orbiter's attitude and maneuvering thruster systems and the spacecraft's guidance and navigation system performance.

Launch Preparations, Countdown and Liftoff - Assembly of the Space Shuttle "stack" for the STS-1 mission began in December 1979, and January 1980, with the erection of the twin solid rocket boosters on a mobile launcher platform in the Kennedy Space Center Vehicle Assembly Building's High Bay 3.

The Space Shuttle Orbiter Columbia arrived at Kennedy Space Center from Dryden Flight Research Center in California aboard the 747 Shuttle Carrier Aircraft on March 24, 1979, and was immediately moved into the Orbiter Processing Facility for systems checkout and the completion of installing its thermal protection system.

The external tank arrived at Kennedy by barge from the Michoud Assembly Facility in New Orleans, La., in July 1979, and underwent processing in the Vehicle Assembly Building's High Bay 4.

The tank was mated with the solid rocket boosters on the mobile launcher platform in early November 1980.

The Columbia was moved from the Orbiter Processing Facility on November 24, 1980, to the adjacent Vehicle Assembly Building where it was mated with the external tank and solid rocket boosters to complete the space vehicle for the STS-1 mission.

The Shuttle Interface Test was conducted in the Vehicle Assembly Building in December 1980 to checkout the mechanical and electrical connections between the various elements and the functioning of onboard flight systems.

The assembled Space Shuttle aboard its mobile launcher platform was moved the 5.6 km (3.5 mi.) from the Vehicle Assembly Building to Pad A on December 29, 1980, to undergo final processing for launch.

Pad/flight vehicle interfaces were validated during January and a further series of tests led to the wet (or fueled) Countdown Demonstration Test which culminated in the successful 20-second Flight Readiness Firing of Columbia's three main engines on February 20, 1981.

Upon the conclusion of the readiness firing, steps were taken to repair a small portion of the external tank's super light ablator insulation which became debonded during a tanking test of the Orbiter's supercold liquid oxygen and liquid hydrogen propellants in Jaunary 1981.

Major tests conducted during March 1981, included the Launch Readiness Verification runs in which flight and landing events were simulated and a "dry" Countdown Demonstration Test. The latter test was a dress rehearsal for launch in which prime crew astronauts John Young and Bob Crippen went through a countdown and simulated liftoff. The dry demonstration test differed from the wet one in that the Shuttle's external tank was not loaded with the Orbiter's liquid hydrogen and liquid oxygen propellants and did not include a test firing of the Orbiter's engines.

The completion of the dry Countdown Demonstration Test and other major tests cleared the way for countdown and launch.

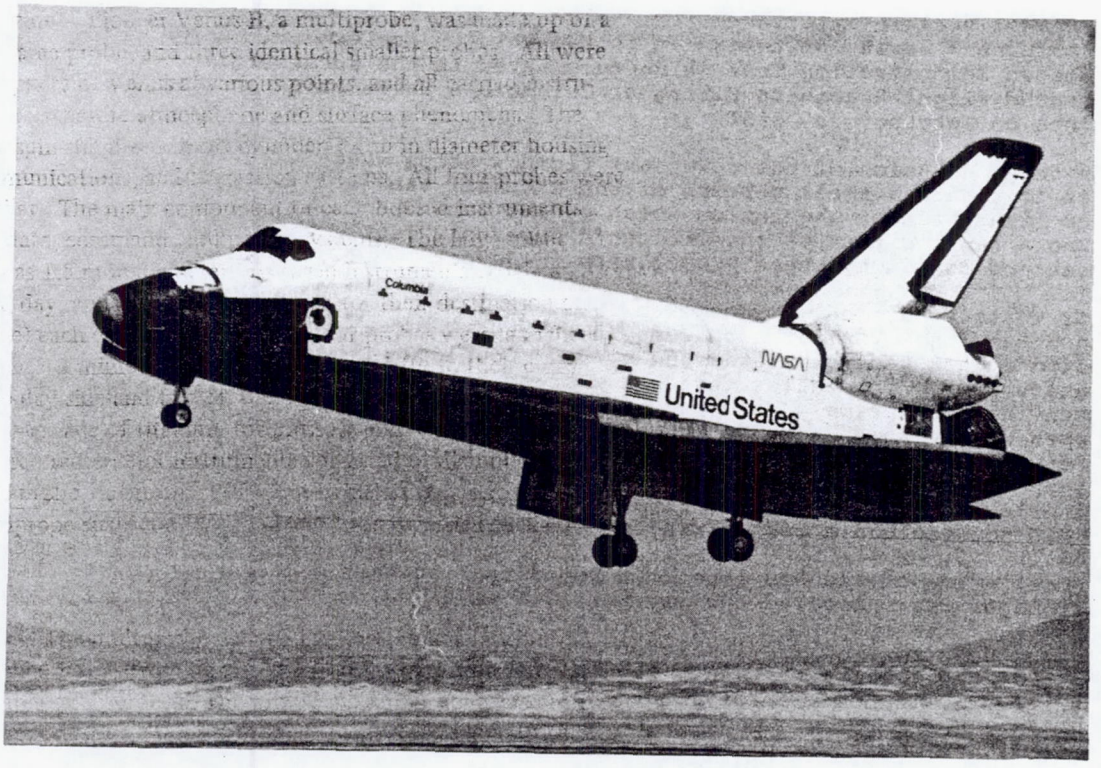
The countdown for the STS-1 mission was conducted in Firing Room 1 of the Complex 39 Launch Control Center by a government/industry launch team of about 200.

The STS-1 pre-count was picked up at the T-73-hour mark and included a number of built-in holds.

The Crew - Crew for the first orbital flight were John W. Young, commander, veteran of two Gemini and two Apollo space flights, and U.S. Navy Capt. Robert L. Crippen, pilot. Crippen had not flown in space.

Project Results - The STS-1 mission was launched at 7:00:03.9 a.m., EST, on April 12, 1981, following an unsuccessful attempt on April 10. The countdown on April 10 proceeded normally until T-20 minutes (20 minutes prior to launch in the countdown sequence) when the Orbiter general purpose computers (GPC's) were scheduled for transition from the vehicle checkout mode to the vehicle flight configuration mode. The launch was held for the maximum time and scrubbed when the four primary GPC's would not provide the correct timing for the backup flight system GPC. Analysis and testing indicated the primary set of GPC's provided incorrect timing to the backup flight system at initialization and caused the launch delay.

The first flight of the Space Shuttle was completed at 10:20:58 a.m., PST, on April 14, 1981, with touchdown of the Orbiter Columbia. The landing was at Edwards Air Force Base, California, 54 hours, 20 minutes, and 54.1 seconds after launch from the Kennedy Space Center, Florida.



Space shuttle orbiter Columbia returns, landing on a runway on the dry lakebeds of the Mojave desert, completing its first orbital mission.

Major Participants - Management of the Space Shuttle Program was shared by NASA Headquarters, NASA centers involved in manned space flight and many aerospace contractors and industries. Overall direction of the Shuttl Program was the responsibility of NASA Headquarters in Washington, D.C. Johnson Space Center was responsible for program management and systems integration and also the development center for the Orbiter. The Marshall Space Flight Center was responsible for development of the External Tank, Solid Rocket Booster and the Shuttl main engines, as well as certain systems test and int tion functions. Kennedy Space Center, responsible fo design of the launch and recovery facilities, served the launch and landing site for missions requiring easterly launches. Goddard Space Flight Center was sible for space tracking and communications.

Hundreds of private firms, educational institution search organizations and Federal agencies were inv in creating the Space Shuttle. Prime contractors key subcontractors are also listed below:

NASA Headquarters

Dr. Alan Lovelace, Acting Administrator; John F. Yardley, Associate Administrator for Space Transportation System; L. Michael Weeks, Deputy Associate Administrator for Space Transportation System; David R. Braunstein, Deputy Associate Administrator for Space Transportation System (Management); Daniel M. Germany, Director, Orbiter Programs; Walter F. Dankoff, Director, Engine Programs; Edward P. Andrews, Director, Ground Systems and Flight Test; LeRoy E. Day, Director, Systems Engineering and Integration; and Frank Van Rensselear, Director, Expendable Equipment.

Johnson Space Center

Christopher C. Kraft, Jr., Director; Robert F. Thompson, Manager, Space Shuttle Program; Donald K. "Deke" Slayton, Manager, Orbital Flight Test; Aaron Cohen, Manager, Space Shuttle Orbiter Project Office; George W. S. Abbey, Director of Flight Operations; Maxime A. Faget, Director of Engineering and Development; Lynwood C. Dunseith, Director of Data Systems and Analysis.

Kennedy Space Center

Richard G. Smith, Director; Gerald D. Griffin, Deputy Director; Raymond L. Clark, Associate Director for STS Development; Dr. Robert H. Gray, Manager, Shuttle Projects Office; George F. Page, Director, Shuttle Operations.

Marshall Space Flight Center

Dr. William R. Lucas, Director; Thomas J. Lee, Deputy Director; Robert E. Lindstrom, Manager, MSFC Shuttle Projects Office; James E. Kingsbury, Director, Science and Engineering Directorate; James B. Odom, Manager, External Tank Project; George B. Hardy, Manager, Solid Rocket Booster Project; James R. Thompson, Jr., Manager, Space Shuttle Main Engine Project; and James M. Sisson, Manager, Engineering and Major Test Management Office.

Dryden Flight Research Center

Isaac T. Gillam IV, Director; Robert F. Johannes, Deputy Director; John A. Manke, Chief of Flight Operations; and Mel Burke, Shuttle Project Manager.

Goddard Space Flight Center

A. Thomas Young, Director; Dr. John H. McElroy, Deputy Director; Richard S. Sade, Director of Networks, Space Tracking and Data Network; Walter LaFleur, Deputy Director of Networks (STDN); William B. Dickinson, Division Chief, NASA Communications Network; Donald D. Wilson, Assistant Chief, NASA Communications Network; and Daniel Spintman, Chief, Network Operations Division.

Contractors -

Orbiter:

Prime Contractor - Rockwell International, Space Division, Downey, Calif.

Subcontracts - Wing, Grumman Aerospace, Bethpage, New York; Vertical Tail, Fairchild Republic, Farmingdale, New York; Mid Fuselage, General Dynamics, San Diego, Calif.; Reusable Surface Insulation, Lockheed Missiles & Space Company, Sunnyvale, Calif.; Orbital Maneuvering System, McDonnell Douglas Astronautics Co., E. St. Louis, Mo.

External Tank:

Prime Contractor - Martin Marietta Aerospace, Denver, Colo.

Subcontracts - Intertank, Avco Corp., Nashville, Tenn.; Dome Cape, General Dynamics, San Diego, Calif.; Ogive and Dome Gores, Aircraft Hydroforming, Gardena, Calif.; Tank Weld Tools, LTV Aerospace, Dallas, Tex.; Gore/Dome Weld Tools, The Boeing Company, Seattle, Wash.

Solid Rocket Booster:

Project Management - Marshall Space Flight Center, Huntsville, Ala.

Subcontracts - Solid Rocket Motor, Thiokol Corp., Brigham City, Utah; Structures, McDonnell Douglas Astronautics Corp., Huntington Beach, Calif.; Decelerator Subsystem, Martin Marietta Aerospace, Denver, Colo.; Integrated Electronics Assembly, Bendix Corp., Teterboro, New Jersey; Booster Separation Motor, United Technology Corp., Sunnyvale, Calif.

Space Shuttle Main Engine:

Prime Contractor - Rockwell International, Rocketdyne Division, Canoga Park, Calif.

Subcontracts - Controller, Honeywell Inc., Minneapolis, Minn.; Hydraulic Actuator System, Hydraulic Research, Valencia, Calif.

NOVA-1

Launch Vehicle - Four-stage Scout G-1 solid propellant launch vehicle.

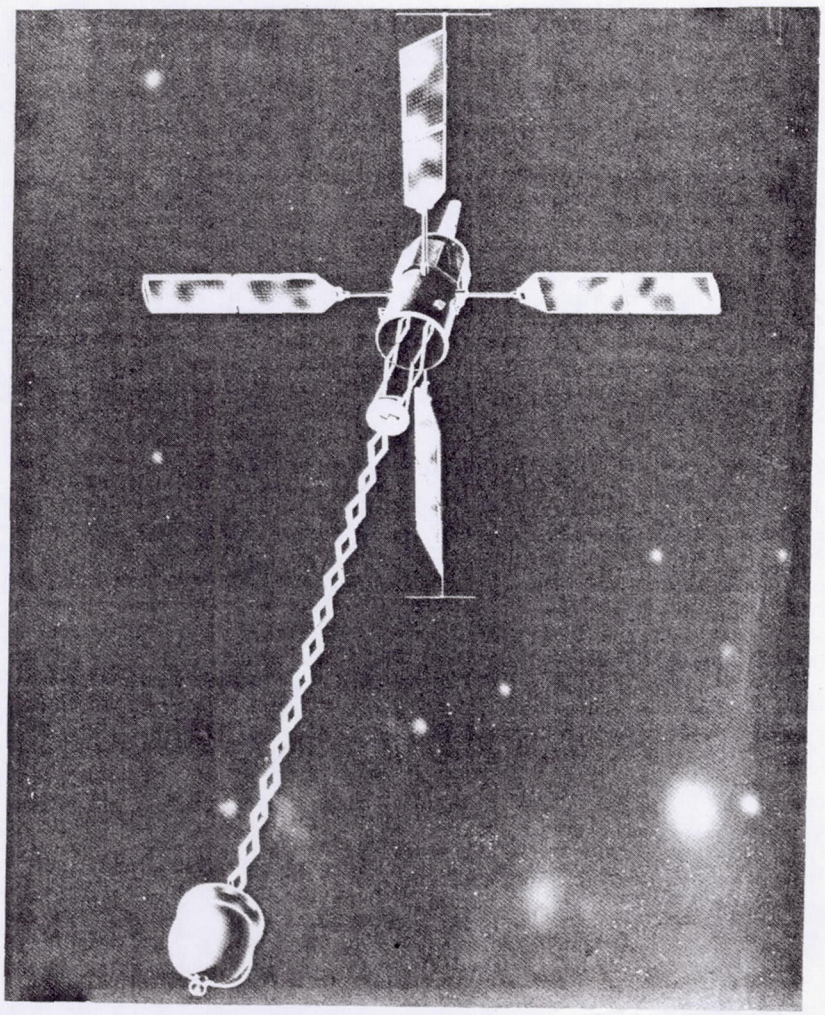
Spacecraft Description - A 368-pound spacecraft which carried a hydrazine motor to raise and circularize the orbit to 600 nautical miles.

Project Objectives - The Navy NOVA-1 spacecraft provided improved operational characteristics for the Transit navigation system. The Transit Program was an operational navigation system used by the U.S. Navy and other vessels for worldwide ocean navigation. When NOVA-1 was launched, there were five operating satellites in the system. Two Scout vehicles were maintained on standby status to launch replacement satellites to fill any operational gaps which might occur in the system.

Project Results - Successfully launched from WTR on May 15, 1981.

Major Participants - NASA and DOD entered into agreements in June 1962 establishing the basis for joint utilization of the Scout launch vehicle. Under this agreement, NASA maintained the Scout launch vehicle system, and the capabilities of the Scout system were utilized by the DOD for appropriate missions.

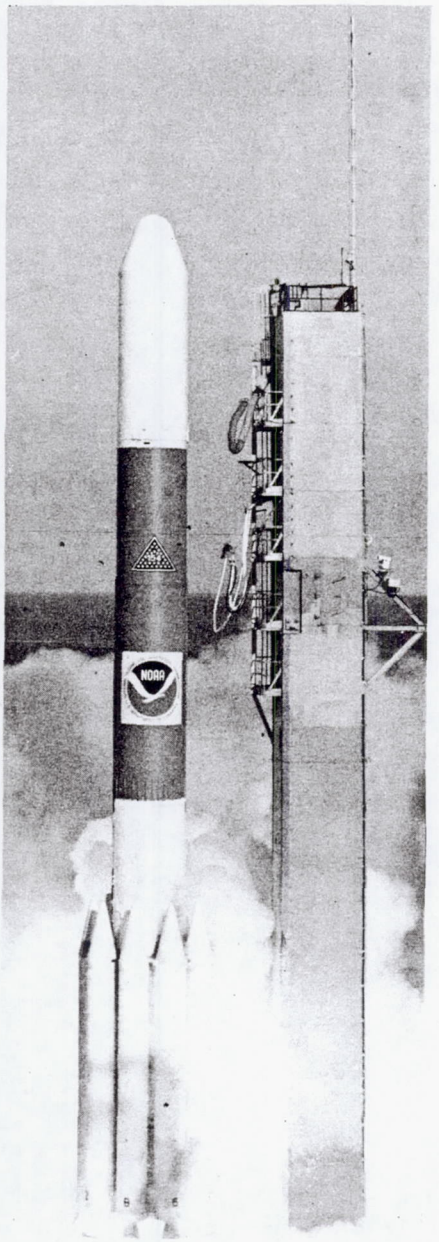
The DOD/Navy has called upon NASA to provide Scout launches for the Navy Transit and NOVA Programs. Fifteen Transit satellites and three Transit Improvement Program satellites had been launched to date. The Navy reimbursed NASA for the cost of Scout launch vehicles, WTR launch services, mission support requirements, and supporting services. The Scout vehicle was managed by the NASA Langley Research Center.



Navy's Nova-1 in artist's conception.

C-9

GOES-5



Delta 154 soars skyward to place Geostationary Operational Environmental Satellite-5 in an egg-shaped transfer orbit to be transformed later into a stationary orbit 22,240 miles above the equator.

Launch Vehicle - Three-stage Delta launch vehicle with the following characteristics: Height, 35.36 m (116 ft.); Maximum Diameter (without attached solids): 2.4 m (8 ft.); Liftoff Weight: 190,631 kg (420,270 lb.); and First Stage Thrust (average with five solids burning): 2,947,245 newtons (662,600 lb.). This was the 154th Delta mission.

Spacecraft Description - The spacecraft was 215 centimeters (85 inches) in diameter, and its overall height 312 cm (123 in.). Weighed 836 kilograms (1,841 pounds) when launched by the Delta 3914 booster, and 397 kg (875 lb.) at beginning of mission life in orbit after firing and ejecting its self-contained solid motor.

The spinning, drum-shaped base of the spacecraft housed the Earth, Sun and X-ray sensors, the energetic particle monitor, and axial and radial thrusters for attitude control. Solar panels were bonded on the entire exterior surface of the drum sides, and a magnetometer was mounted on a boom situated at the edge of the drum. Contained within, but protruding from, the base at the center was the primary instrument, the Visible Infrared Spin-Scan Radiometric Atmospheric Sounder (VAS), and its sunshade.

The S-band high gain antenna, the UHF antenna and the S-Band omni-directional antenna were mounted atop the VAS housing and were mechanically despun by an electric motor so as to point at the Earth while the base was spinning for stability.

Project Objectives - GOES-5 was the seventh spacecraft in the SMS/GOES series--Geostationary Operational Environmental Satellites placed into Earth synchronous orbits to provide near continual, high resolution visual and infrared imaging over large areas of North and South America and surrounding oceans at least every 30 minutes; to collect environmental data from up to 10,000 remote observing platforms on land, in the ocean and in the air; to measure energetic solar particle flux, x-rays, and the strength of the Earth's magnetic field; and, to broadcast centrally prepared weather and satellite information.

GOES-5, like its predecessor GOES-4, contained an experimental, advanced type of meteorological sensor which not only observed the traditional visible light and infrared images of cloud formations and motion, but also, on command, temperature variations with light in the atmosphere and could map the distribution of water vapor in the air. This instrument was called the Visible Infrared Spin-Scan Radiometric Atmospheric Sounder (VAS) and was shown to have significant meteorological use as a geosynchronous temperature sounder during its initial experimental runs with the GOES-4 VAS between October 1980 and January 1981.

GOES-5 cost about $20 million and its launch by a Delta 3914 launch vehicle an additional $16 million. NASA funded the development of the VAS instrument, while NOAA was paying for the VAS on GOES-5, plus satellite construction and launch costs.

Once checked out by NASA, the new spacecraft was under the control of NOAA's National Earth Satellite Service, which made the imagery and digital data available to users worldwide through its distribution network.

Spacecraft Payload - The spacecraft instrumentation included: The Visible Infrared Spin-Scan Radiometric Atmospheric Sounder (VAS), an instrument incorporating the functions of the Visible Infrared Spin-Scan Radiometer (VISSR) flown on GOES-1, 2, and 3, with a new capability for geostationary satellites--atmospheric sounding.

The Space Environmental Monitor (SEM) included a magnetometer, a solar x-ray telescope and an energetic particle monitor, designed to provide direct quantitative measurements of the important effects of solar activity for use in real time solar forecasting and subsequent research. This subsystem, which detected unusual solar flares with high levels of radiation, measured the intensity of solar winds, and measured the strength and direction of the Earth's magnetic field, was the same as on previous GOES satellites plus the addition of the High Energy Proton and Alpha Detector (HEPAD) to expand the dynamic range.

The Data Collection System (DCS) provided communications relay from data collection platforms on land, at sea, and in the air to the command and data acquisition station and the interrogation of platforms via the satellite.

The Telemetry, Tracking and Command (TTC) subsystem used S-band frequencies for transmission of wideband video data and for relay of data via the spacecraft to facilities operated by NOAA's National Earth Satellite Service in Suitland, Md.

Project Results - Successfully launched by NASA's Kennedy Space Center, Fla., on May 22, 1981. Satellite in geo-synchronous orbit.

Major Participants -

Key Spacecraft Personnel

Project Manager, R. H. Pickard, NASA/Goddard Space Flight Center; Project Scientist, W. E. Shenk, NASA/Goddard Space Flight Center; and Manager, A. J. Cervenka, NASA Headquarters.

Experiment	Experiment Personnel		Affiliation
VISSR Atmos Sounder	PI	NESS Staff	NOAA-NESS
	OI	W. E. Shenk	NASA-GSFC
Solar Energetic Particles	PI	D. J. Williams	NOAA-ERL
	OI	H. H. Sauer	NOAA-ERL
	OI	R. N. Grubb	NOAA-ERL
Solar X-ray Monitor	PI	D. J. Williams	NOAA-ERL
	OI	R. F. Donnelly	NOAA-ERL
Biaxial Fluxgate Magnetometer	PI	D. J. Williams	NOAA-ERL
	OI	R. N. Grubb	NOAA-ERL
	OI	J. C. Joselyn	NOAA-ERL
Meteo Data Collection System	PI	NESS Staff	NOAA-NESS

NOAA/NESS

Edward W. Bisone, GOES Spacecraft Manager; James C. Fischer, Payload Coordinator; Thomas J. Karras, Manager, Satellite Operational Control Center and Acting Chief, Satellite Operations Division; Gary K. Davis, GOES-E Operations Readiness Team Leader; Everitt W. Kendall, Manager, Command and Data Acquisition Station (Wallops Island); William C. Callicott, Chief, Information Processing Division; and Donald C. Winner, Chief, Satellite Services Division.

NASA Headquarters

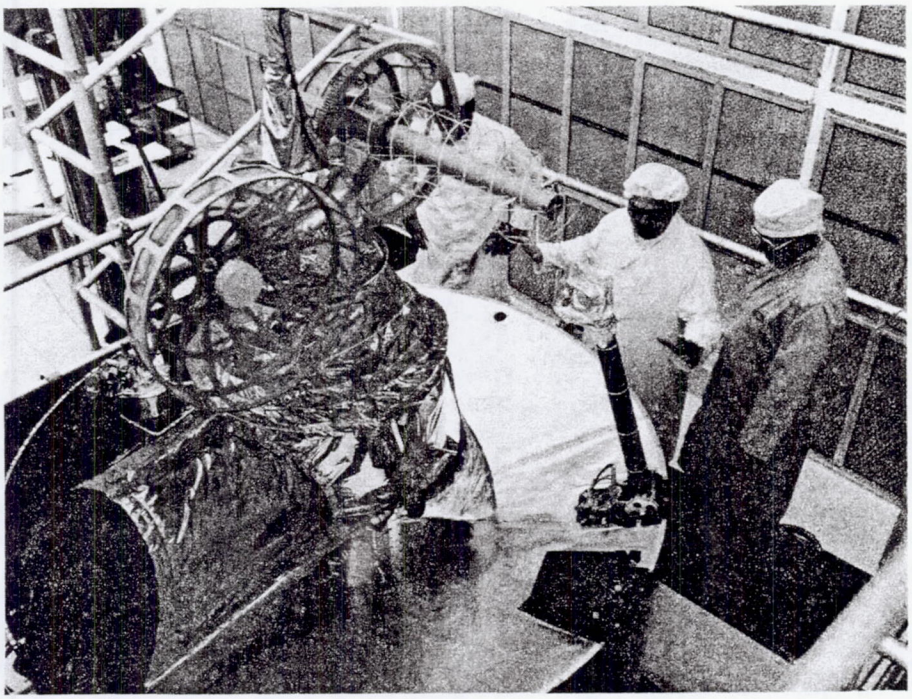
Dr. Anthony J. Calio, Associate Administrator for Space and Terrestrial Applications; Samuel W. Keller, Deputy Associate Administrator for Space and Terrestrial Applications; L. R. Greenwood, Director, Environmental Observation Division; W. P. Bishop, Deputy Director, Environmental Observation Division; R. J. Arnold, Program Manager, Operational Meteorological Satellites; T. Perry, Program Manager, Geostationary Operational Environmental Satellites; S. G. Tilford, Chief, Atmospheric Processes Branch; J. C. Dodge, Manager, Severe Storms and Local Weather Research Program; Dr. Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joseph B. Mahon, Director, Expendable Launch Vehicles Program; Peter Eaton, Program Manager, Delta Launch Vehicle; R. E. Smylie, Associate Administrator for Tracking and Data Acquisition.

Goddard Space Flight Center

A. Thomas Young, Director; John H. McElroy, Deputy Director; William C. Keathley, Director of Projects; Paul A. Mowatt, Associate Director for GOES and Delta.

Hughes Aircraft Company

Albert D. Wheelon, Vice President/Group Executive, Space and Communications Group; C. Richard Jones, Manager, NASA Division; Marvin S. Mixon, Manager, Metsat Programs, NASA Division; Louis R. Fermelia, Manager, GOES Program.



Technicians install part of the delicate communications system on top of the Geostationary Operational Environmental Satellite-5 (GOES-5).

Major Contractors

McDonnell Douglas Astronautics Company, Huntington Beach, Calif., Delta launch vehicle; Hughes Aircraft Company, Space and Communications Group, El Segundo, Calif., GOES-E spacecraft; Hughes Aircraft Company, Santa Barbara Research Center, Santa Barbara, Calif., VAS instrument; Ball Aerospace, Boulder, Colo., SEM instrument; Panametrics, Inc., Boston, Mass., SEM instrument; Ford Aerospace and Communications Corp., Palo Alto, Calif., SEM instrument; Hughes Aircraft Company, Hughes Technology Division, Space and Communications Group, El Segundo, Calif., TCC subsystem and DCS system.

INTELSAT V-B

Launch Vehicle - Intelsat V-B was launched by the Atlas Centaur, NASA's standard launch vehicle for intermediate weight payloads. The launch vehicle had the following general characteristics: height: 40.8 meters (134 feet) including nose fairing; diameter: 3.05 m (10 feet); total liftoff weight: 147,926 kg (326,120 lb.) including spacecraft; and liftoff thrust: 1,917,088 newtons (431,000 lb.) sea level.

Spacecraft Description - Intelsat V-B weighed 1,928 kilograms (4,251 pounds) at launch and had almost double the communications capability of earlier satellites in the Intelsat series --12,000 voice circuits and two color television channels. It was positioned in geosynchronous orbit over the Atlantic Ocean as the prime Intelsat satellite to provide communications services between the Americas, Europe, the Middle East, and Africa.

Dimensions and structure--Solar array, 15.6 meters (51.1 feet); Main Body "Box," 1.66 x 2.01 x 1.77 meters (5.4 x 6.6 x 5.8 feet); height, 6.4 meters (21.0 feet); width (fully deployed), 6.8 meters (22.25 feet); weight (at launch, without MCS), 1,928 kilometers (4,251 pounds).

Spacecraft--aluminum main body structure; graphite epoxy antenna tower; catalytical and electrothermal hydrazine thrusters.

General Characteristics--three-axis body stabilized with Sun and Earth sensors and momentum wheel; wing-like, Sun-oriented solar array panels producing a total of 1,241 watts of electrical power after 7 years in orbit; modular construction; 7-year expected life in orbit.

Communications Characteristics: Capacity average 12,000 simultaneous two-way telephone circuits and two television channels, utilized both 14/11 GHz frequency band; the 14/11 GHz frequency band was used twice through east and west spot beams; six communications antennas--two global coverage horns, two hemispherical/zone offset-fed reflectors and two offset-fed spot beam reflectors.

Spacecraft Payload - INTELSAT-IV was the first INTELSAT satellite to have the following features: frequency reuse through both spatial isolation and dual polarization isolation; multi-band communications--both 14/11 GHz and 6/4 GHz; a contiguous band output multiplexer; maritime communications subsystem (MCS). In designing INTELSAT-V, engineers had to work within a number of limiting factors to achieve the communications capacity required. Typical of these were: limitations on the available frequency bands; the maximum mass which could be placed in orbit by the then (1973+) only available launch vehicle--Atlas Centaur.

Project Results - Successfully launched from the Eastern Space and Missile Center on May 23, 1981.

Major Participants - INTELSAT awarded a contract for the development and manufacture of INTELSAT V satellites to Ford Aerospace and Communications Corporation as prime contractor and Communications Corporation as prime contractor and an international team of manufacturers as subcontractors. Major participants included:

INTELSAT

Andrea Caruso, Deputy Director General--Administration; Francis Latapie, Acting Deputy Director General--Administration; and Allan M. McCaskill, Manager, Launch Vehicle Program Office.

NASA Headquarters

Stanley I. Weiss, Associate Administrator for Space Transportation Operations; J. B. Mahon, Director, Expendable Launch Vehicles; and F. R. Schmidt, Atlas-Centaur Manager.

Lewis Research Center

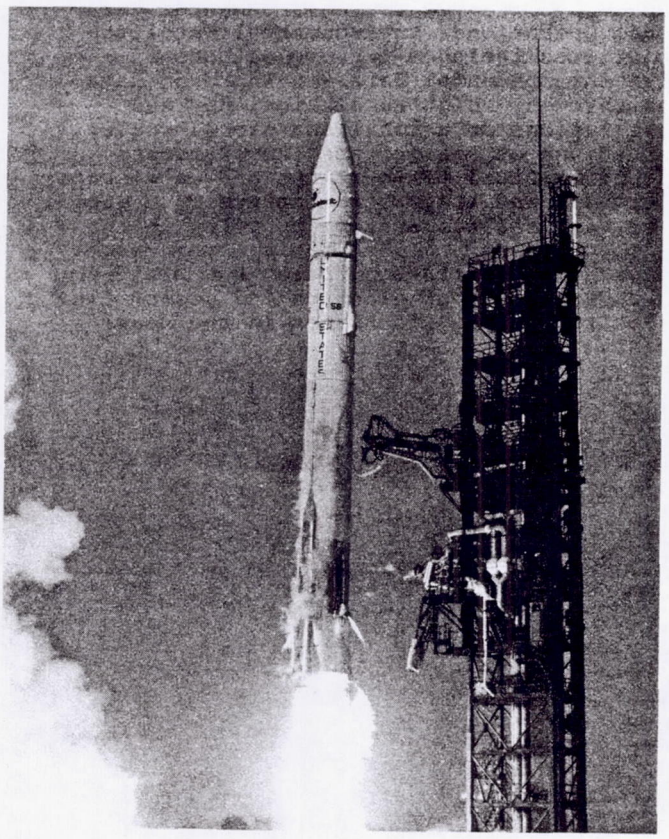
James E. Patterson, Director, Launch Vehicles; and Richard E. Orzechowski, Mission Project Engineer.

Kennedy Space Center

Charles D. Gay, Director, Expendable Vehicles Operations; John D. Gossett, Chief, Centaur Operations Division; Donald G. Sheppard, Chief, Automated Payloads Division; and Larry F. Kruse, INTELSAT Spacecraft Coordinator.

Prime Contractors

Ford Aerospace & Communications Corporation, Palo Alto, Calif., INTELSAT V Spacecraft; General Dynamics/Convair, San Diego, Calif., Atlas-Centaur Vehicle; Honeywell, Aerospace Division, St. Petersburg, Fla., Centaur Guidance Inertial Measurement Group; Pratt & Whitney, West Palm Beach, Fla., Centaur RL-10 Engines; Teledyne Systems Co., Northridge, Calif., Digital Computer Unit/ PCM Telemetry.



Atlas Centaur 56 carrying INTELSAT V-B, a commercial communications satellite. This was the second in a series of nine of the high capacity communications satellites launched by NASA for INTELSAT. INTELSAT V's, the largest and highest capacity communications satellites built, could simultaneously carry 12,000 two way telephone calls and two color TV channels.

NOAA-7/C

Launch Vehicle - A modified Atlas-F launch vehicle; overall including the spacecraft fairing was 28.1 meters (92.26 feet). The Atlas-F was powered by liquid oxygen (LOX) and a liquid hydrocarbon fuel. The booster system consisted of two fixed thrust engines which gimbaled to provide pitch, yaw and roll control to the vehicle from just before booster engine cutoff until sustainer cutoff. Following booster staging, two vernier engines provided roll control. After sustainer cutoff the vernier engines provided fine trajectory corrections.

Spacecraft Description - The NOAA-7 satellite was an integrated spacecraft system designed to provide for, and control injection into, the required orbit after separation from the Atlas-F launch vehicle.

The spacecraft, including the apogee kick motor, in the launch configuration was 371 centimeters (146 inches) high and 188 cm (74 in.) in diameter and weighed 1,405 kilograms (3,097 pounds). On orbit, with the kick motor and reaction-control equipment expendables consumed, the satellite had a nominal weight of 723 kilograms (1,594 pounds).

The solid rocket apogee kick motor, which performed the orbit injection maneuver, was an integral part of the NOAA-7 spacecraft. It contained 664 kilograms (1,464 pounds) of propellant which burned to depletion in 45 seconds, leaving the empty motor assembly case, weighing 50.4 kilograms (111 pounds), in orbit with the spacecraft. During the motor burn the spacecraft was stabilized by nitrogen and hydrazine thrusters.

Project Objectives - NOAA-7 was the fourth of eight TIROS-N series operational meteorological polar orbiting spacecraft. The purpose of these satellites was to make measurements of temperature and humidity in the Earth's atmosphere, surface temperature, surface and cloud cover, water-ice-moisture boundaries, and proton and electron flux near the Earth. They had a capability of receiving, processing, and retransmitting data from free-floating balloons, buoys, and remote automatic stations distributed around the globe and could also track stations which are in motion.

NOAA-7 objectives included collection of environmental data for use in the National Operational Environmental Satellite System. Specific objectives included improve methods of obtaining quantitative environmental data and improved data handling capabilities through: high resolution, day and night cloud cover observations on a local and global scale; high resolution observations of sea surface temperatures; improved observations of vertical temperatures and water vapor profiles in the troposphere and lower stratosphere on a global basis; observations of vertical temperature profiles in the middle and upper stratosphere on a global basis; operational flight of a high-capacity data collection/relay and platform location system; and observations of electron and proton flux densities and total particle energy densities in the near-Earth space environment.

Project Payload - The spacecraft bus consisted of these subsystems: structure-thermal, power, attitude determination and control, and communications and data handling.

Project Results - Launched from Western Test Range on June 23, 1981.

Major Participants -

NOAA/NESS

Arthur Schwalb, Chief, Oceanic and Atmospheric Satellite Systems; Dario Galoppo, Payload Coordinator; Thomas J. Karras, Manager, Satellite Operations Control Center; Gary K. Davis, NOAA-C Operations Readiness Team Leader; Everitt W. Kendall, Manager, Command and Data Acquisition Station (Wallops Island); William C. Callicott, Chief, Information Processing Division; Donald C. Winner, Chief, Satellite Services Division.

NASA Headquarters

Dr. Anthony J. Calio, Associate Administrator for Space and Terrestrial Applications; Samuel W. Keller, Deputy Associate Administrator for Space and Terrestrial Applications; Dr. Lawrence R. Greenwood, Director, Environmental Observations Division; W. P. Bishop, Deputy Director, Environmental Observations Division; Tom W. Perry, Deputy Program Manager, Operational Meteorological Satellites; S. G. Tilford, Chief of Atmospheric Processes Branch; W. S. Wilson, Chief, Oceanic Processes Branch; J. S. Theon, Program Scientist, Global Weather Research; Dr. Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joseph B. Mahon, Director, Expendable Launch Vehicles Program; Jay A. Salmanson, Program Manager, Atlas Launch Vehicle; and R. E. Smylie, Associate Administrator for Tracking and Data Systems.

Goddard Space Flight Center

A. Thomas Young, Director; William C. Keathley, Director, Flight Projects Directorate; G. W. Longanecker, Project Manager; Dr. William N. Redisch, Deputy Project Manager; John A. Underwood, Deputy Project Manager, Resources; William M. Peacock, Spacecraft Manager; Lawrence T. Draper, Instrument Manager; John F. Corrigan, Launch Vehicle Manager; and David K. Coolidge, Mission Operations Manager.

Contractors

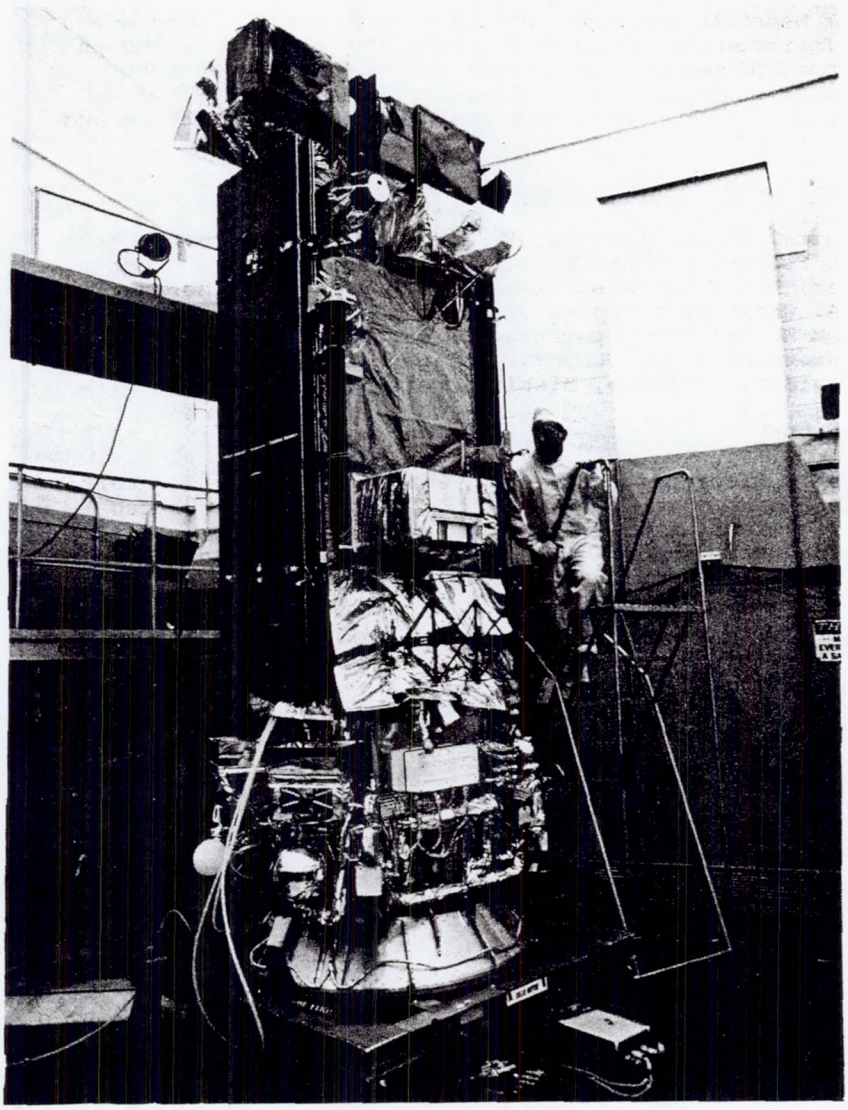
RCA Astro Electronics Division, Princeton, NJ, spacecraft; ITT-Aerospace/Optical Division, Ft. Wayne, IN, Advanced Very High Resolution Radiometer/2; ITT-Aerospace/Optical Division, Ft. Wayne, IN, High Resolution Infrared Radiometer Sounder/2; Jet Propulsion Laboratory, Pasadena, Calif.,

Microwave Sounding Unit; Ford Aerospace Communications Corp., Palo Alto, Calif., Space Environment Monitor; Marconi Space and Defence Systems, Frimley, United Kingdom, Stratospheric Sounding Unit; Electroniques Marcel Dassault, Paris, France, ARGOS System (DCS); Jet Propulsion Laboratory, Pasadena, Calif., Contamination Monitor; General Dynamics Corp., San Diego, Calif., Atlas-F Launch Vehicle; and Thiokol Corp., Huntsville, Ala., Apogee Kick Motor.

Key Spacecraft Personnel

Manager, R. J. Arnold, NASA Headquarters; Project Manager, G. A. Branchflower, Goddard Space Flight Center; and Project Scientist, A. Arking, Goddard Space Flight Center.

Experiment	Experiment Personnel		Affiliation
Advanced Very High Resolution Radiometer	PI	NESS Staff	NOAA-NESS
	CO	W. E. Shenk	NASA-GSFC
Operational Vertical Sounder	PI	NESS Staff	NOAA-NESS
Data Collection System	PI	NESS Staff	NOAA-NESS
Space Environment Monitor	PI	D.J. Williams	NOAA-ERL
	OI	H. H. Sauer	NOAA-ERL
	OI	C. O. Bostrom	Applied Physics Lab
	OI	R. N. Grubb	NOAA-ERL



NOAA-7, a new environmental monitoring satellite, from which improved sea surface temperature information of growing significance to the fishing and marine transportation industries, weather forecasters, and others could be determined, was launched June 23, 1981. The photo shows pre-launch testing.

Dynamics Explorer A & B

Launch Vehicle - Delta booster with the following characteristics:

The first stage was a modified Thor booster incorporating nine strap-on solid fuel rocket motors. The main engine was gimbal-mounted to provide pitch and yaw control from liftoff to main engine cutoff. Two liquid-propellant vernier engines provided roll control throughout first stage operations and pitch and yaw control from main engine cutoff to first stage separation.

The second stage was powered by a liquid-fuel, pressure fed engine, also gimbal-mounted to provide pitch and yaw control through second-stage burn. A nitrogen gas system using six fixed nozzles provided roll control during powered and coast flight, as well as yaw and pitch control after second stage was achieved by thrust from nitrogen gas jets. Two fixed nozzles fed by the propellant-tank helium pressurization system provided retro-thrust after Dynamics Explorer-B spacecraft separation.

The Dynamics Explorer-A spacecraft was attached to the Delta third stage by means of a payload attach fitting which incorporates the separation system. The Delta fairing was attached to the forward face of the second stage and is 7.9 meters (312 inches) long and 2.4 meters (96 inches) wide.

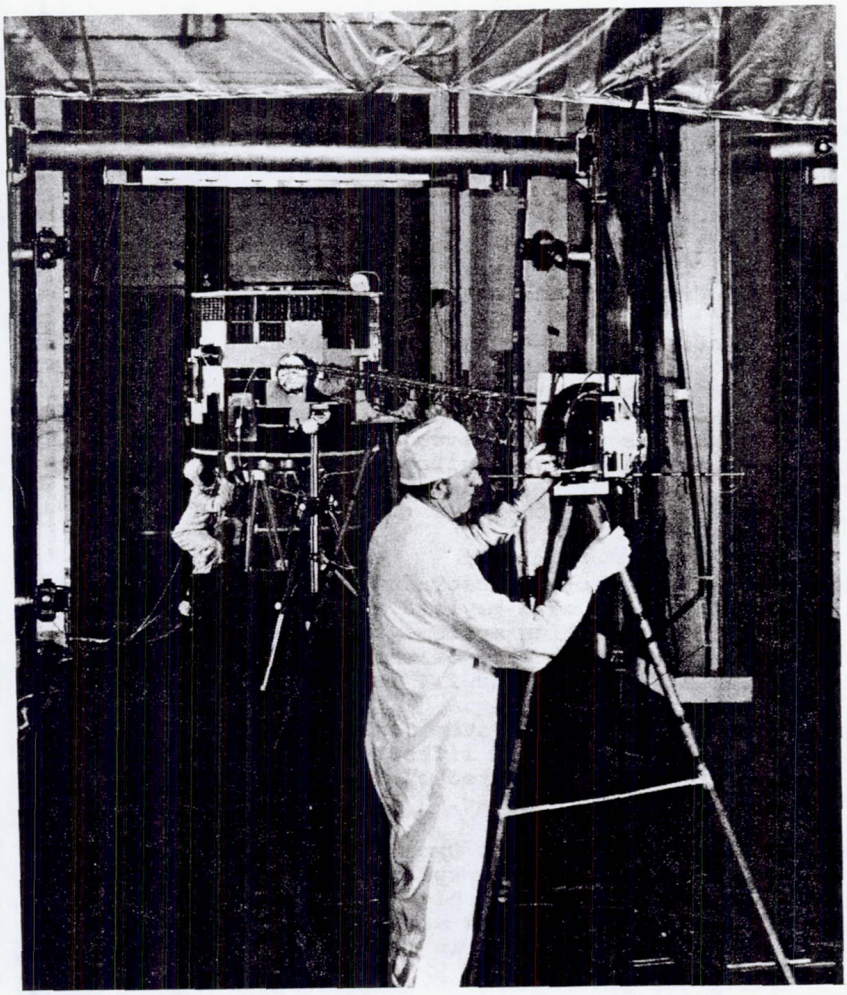
An all-inertial guidance system controlled the vehicle and sequence of operations from liftoff to spacecraft separation. This guidance system consisted of an inertial sensor package and digital guidance computer.

The low-altitude spacecraft, Dynamics Explorer-B, was separated first into its orbit and was spin stabilized at separation from the Delta vehicle. The high-altitude spacecraft, Dynamics Explorer-A, was spun up by the Delta spin table before the Delta third stage injected it into orbit.

Spacecraft Description - Two spacecraft, each was a 16-sided polygon approximately 1.35 meters (53 inches) wide and 1.14 m (45 in.) high consisting of baseplates, center column, separation adapter, shear webs, and hat structure. The structure provided mounting surfaces for the outer shells, instruments, electronic packages, attitude control systems, S-Band antenna, and launch vehicle adapter.

Solar array "hats," provided 7,200 square inches of mounting area for the solar cells to supply the necessary power to operate the spacecraft.

The Dynamics Explorer-A spacecraft weighed 403 kg (888 lb.) including 105 kg (231 lb.) of instruments. The Dynamics Explorer-B spacecraft weighed 415 kg (915 lb.) including 111 kg (245 lb.) of instruments.



The Dynamics Explorer-A undergoing preflight evaluation testing in the Magnetic Test Facility at NASA's Goddard Space Flight Center. With its sister spacecraft DE-B, it was stacked in tandem atop a conventional (nine strap-on thrust assist solid propellant motors) Delta booster and placed into coplanar polar orbits. They explored a boundary region between earth and space that affects the atmosphere, auroral displays, radio transmissions, climate and weather. Visible in foreground is one of DE-B's two foot rigid support masts which functioned in concert with two 13 foot-long tubular antennas and two 328-foot wire antennas for the scientific data acquisition instruments onboard.

Project Objectives - Dual spacecraft, Dynamics Explorers A and B, objectives were to study space around Earth from the limits of the upper atmosphere to distances far out in the Earth's magnetic field. Doing so they complemented the work of two previous sets of satellites and prepared the stage for a fourth program that will provide a comprehensive assessment of the energy balance in near-Earth space.

The dual Dynamics Explorer satellites acquired data simultaneously in the magnetosphere by one spacecraft and in the ionosphere and atmosphere with the second. Since the Earth's magnetic field couples energy and particles between these regions, operations were especially planned to acquire data at two altitudes along the same magnetic field line. This was one reason for the coplanar orbits, which was a unique configuration for satellites.

Dynamics Explorer-A moved in a high orbit, up to 25,000 km (15,500 mi.) above the Earth. It carried video cameras to photograph the changing patterns of the northern lights, which are excellent signatures of the transfer of massive amounts of energy from the magnetosphere to the upper atmosphere.

Dynamics Explorer-B, skimmed above the atmosphere from pole to pole. Because of its lower orbit, it moved much faster and made many more observations of the polar regions. More importantly, it passed through the upper atmosphere and ionosphere, where the external disturbances are most intense and easier to measure.

Spacecraft Payload - Both spacecraft were equipped with many instruments, some using booms and antennas as long as 100 meters (328 feet), sticking in all directions away from the spacecraft bodies. Solar cell arrays mounted on the 1.36-meter (53.5-inch)-diameter spacecraft bodies supplied the electrical energy needed to run the instruments and to telemeter the data to receiving stations on the ground. Weight of the combined payload was approximately 820 kilograms (1,800 pounds), with Dynamics Explorer-A weighing 403 kg (888 lb.) and Dynamics Explorer-B weighing 415 kg (915 lb.).

Project Results - Successfully launched from Western Test Range on August 3, 1981. The nominal and actual orbital parameters were as follows:

	DE-2		DE-1	
	Nominal	Actual	Nominal	Actual
Apogee (km)	1300	1012.5	24,875	23,173
Perigee (km)	305	309	683	569.5
Inclination (deg)	90.0	89.99	90.0	89.91
Period (min)	101	97.5	440	409

Although the orbits achieved were somewhat lower than predicted, they were suitable to carry out the scientific mission.

Major Participants -

NASA Headquarters

Andrew J. Stofan, Acting Associate Administrator for Space Science; Franklin D. Martin, Director, Astrophysics Division; Richard Halpern, Chief, Research Flight Program Development; Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joseph B. Mahon, Director, Expendable Launch Vehicle Program; Peter Eaton, Manager, Delta Launch Vehicles; R. E. Smylie, Associate Administrator for Space Tracking and Data Acquisition.

Goddard Space Flight Center

A. Thomas Young, Director; John H. McElroy, Deputy Director; William C. Keathley, Director of Flight Projects; Robert Lynn, Deputy Director of Flight Projects; David W. Grimes, Delta Project Manager; William Russell, Delta Project Deputy Manager, Technical; William Burrowbridge, Delta Mission Integration Manager; James Moore, Deputy Project Manager; Charles Rhoads, Deputy Project Manager, Resources; Warner Hord, Spacecraft Manager; Keith Fellerman, Instrument Manager; Carl E. Gustafson, Mission Operations Manager; Eugene Willingham, Project Operations Director; Joseph Ryan, Project Launch Operations Manager; Robert I. Seiders, Network Support Manager; John B. Zegalia, Mission Support Manager; Clyde Freeman, Science Data Processing Systems Manager.

Kennedy Space Center

Richard G. Smith, Director; Thomas S. Walton, Director of Cargo Operations; Charles D. Gay, Director, Expendable Vehicles Operations; D. C. Sheppard, Chief, Automated Payloads Division; Wayne L. McCall, Chief, Delta Operations Division; C. R. Fuentes, Spacecraft Coordinator; and Ray Kimlinger, Chief, Delta Western Operations Branch.

RCA

Donald G. Shipley, Dynamics Explorer Program Manager; William V. Fuldner, Dynamics Explorer Deputy Program Manager; Ronald C. Maehl, Manager, Dynamics Explorer Science Accommodation.

Key Spacecraft Personnel		Affiliation
PS	R. A. Hoffman	NASA-GSFC
SC	E. R. Schmerling	NASA Headquarters
MG	M. B. Weinreb	NASA Headquarters
PM	G. D. Hogan	NASA-GSFC

Experiment	Experiment Personnel		Affiliation
Magnetic Field Obs.	PI	M. Sugiura	NASA-GSFC
	OI	B. G. Ledley	NASA-GSFC
	OI	W. H. Farthing	NASA-GSFC
	OI	L. J. Cahill, Jr.	U. of Minnesota
Plasma Wave Instrument	PI	S. D. Shawhan	U. of Iowa
	OI	D. A. Gurnett	U. of Iowa
Spin Scan Auror. Imager	PI	L. A. Frank	U. of Iowa
	OI	K. L. Ackerson	U. of Iowa
	OI	R. L. Carovillano	Boston College
	OI	R. H. Eather	Boston College
Retard. Ion Mass Spec.	PI	C. R. Chappell	NASA-MSFC
	OI	P. M. Banks	Stanford U
	OI	W. B. Hanson	U. of Texas, Dallas
	OI	J. H. Hoffman	U. of Texas, Dallas
	OI	A. F. Nagy	U. of Michigan
	OI	G. R. Carignan	U. of Michigan
Hi. Alt. Plasma Instrument	OI	R. A. Hoffman	NASA-GSFC
	OI	J. D. Winningham	Southwest Res Inst.
	OI	D. M. Klumpar	U. of Texas, Dallas
	PI	J. L. Burch	Southwest Res. Ins.
Energetic Ion Composition Spec.	PI	E. G. Shelley	Lockheed Palo Alto
	OI	R. G. Johnson	Lockheed Palo Alto
	OI	R. D. Sharp	Lockheed Palo Alto
	OI	J. Geiss	U. of Berne
	OI	P. X. Eberhardt	U. of Berne
	OI	H. Balsiger	U. of Berne
	OI	D. T. Young	U. of Berne
	OI	A. Ghielmetti	U. of Berne
	OI	B. A. Whalen	National Research Council of Canada

Experiment	Experiment Personnel		Affiliation
Auroral Physics Investigation	PI	F. V. Coroniti	U. of Calif., LA
	OI	C. F. Kennel	U. of Calif., LA
	OI	J. E. Maggs	U. of Calif., LA
Cont. +Nat. Wave-Part. Interact	PI	R. A. Helliwell	Stanford U.
	OI	T. F. Bell	Stanford U.
	OI	D. L. Carpenter	Stanford U.
	OI	C. G. Park	Stanford U.
	OI	J. B. Reagan	Lockheed Palo Alto

FLTSATCOM-E

Launch Vehicle - Atlas Centaur (AC-59) placed FLTSATCOM-E into a highly elliptical orbit of 167 by 35,970 kilometers (104 by 22,351 miles). After reorientation of the satellite, a solid propellant rocket motor aboard the spacecraft was fired to circularize the orbit at an Earth-synchronous altitude. This was the 57th launch of an Atlas Centaur. NASA is reimbursed for all costs of the Atlas Centaur and launch services by the Department of Defense.

Spacecraft Description - The FLTSATCOM spacecraft consisted of two major hexagonal elements, a payload module and a spacecraft module. A majority of the electronic equipment was mounted on 12 panels that enclosed the payload and spacecraft modules.

The payload module, which was fastened to the six corners of the spacecraft module, contained the UHF and X-band communications equipment and antennas. The UHF transmit antenna was made of ribs and mesh that opened like an umbrella, and the receive antenna was a separate, deployable helix.

The spacecraft module contained the Earth sensors, apogee kick motor, attitude and velocity control, telemetry tracking and command (TT&C), electrical power distribution, and the solar array.

The solar array was folded around the spacecraft module prior to its final position in orbit where it was deployed by spring loaded hinges. It was exposed to sunlight in both the deployed and folded positions.

During the transfer orbit operations and through apogee kick motor burn, the spacecraft was spin stabilized. After apogee kick and motor burn, the spacecraft was despun, solar arrays and the UHF antenna were deployed, and the Sun and Earth were acquired. In normal on-orbit operations, the spacecraft was pointed at the center of the Earth by Earth sensors, roll/yaw jets, and a reaction wheel. The solar array was usually normal to the orbit plane and was rotated at a uniform rate to point at the Sun. Rotation was achieved by a clocked drive with command correction available.

A redundant monopropellant hydrazine thruster system was provided for spacecraft control and velocity maneuvers. A solid propellant apogee kick motor injected the spacecraft into a circular, near-synchronous orbit.

Solar arrays and batteries interfaced with a command electrical power bus which distributed primary power to the subsystem equipment converters.

Project Objective - Place FLTSCOM-E in a geostationary orbit at 73 degrees west longitude above the equator, to provide two-way communications in the 240 to 400 MHz frequency band, between any two points on Earth visible from its orbital location. The spacecraft had a design life of 5 years.

Spacecraft Payload - The spacecraft provided 23 UHF and one SFH communications channels including: Fleet broadcast, channel 1; Fleet relay, channels 2 through 10; Air Force narrowband, channels 111 through 22; and a DOD wideband, channel 23.

Project Results - Successfully launched from the Kennedy Space Center on August 6, 1981.

Major Participants -

NASA Headquarters

Dr. Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joseph B. Mahon, Director, Expendable Launch Vehicles; F. R. Schmidt, Manager, Atlas Centaur Launch Vehicle.

Lewis Research Center

Dr. John F. McCarthy, Jr., Director; Dr. John Klineberg, Associate Director; Lawrence J. Ross, Director, Space; J.E. Patterson, Chief, Vehicles Engineering Division; S. V. Szabo, Jr., Deputy Chief, Launch Vehicles Division; Kenneth A. Adams, FLTSATCOM Mission Project Engineer; and Richard W. Heath, FLTSATCOM Vehicle Engineer.

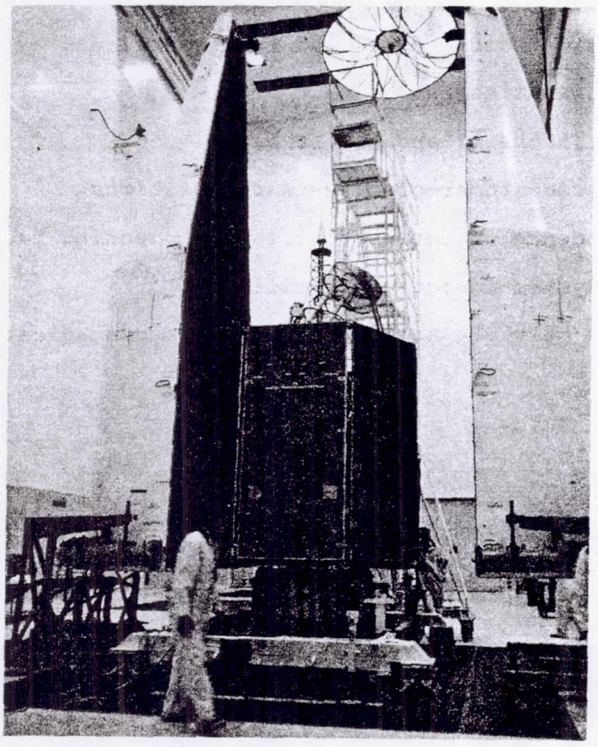
Kennedy Space Center

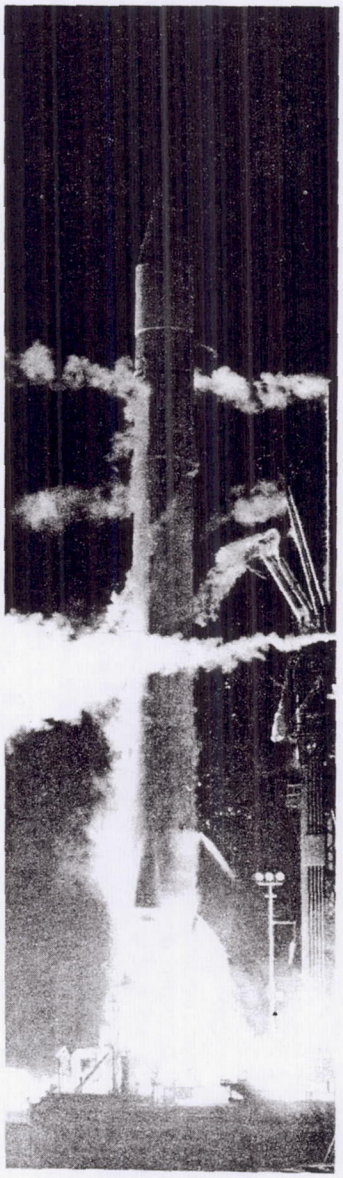
Richard G. Smith, Director; Thomas S. Walton, Director, Cargo Operations; Charles D. Gay, Director, Deployable Payloads Operations; John Gossett, Chief, Centaur Operations, Barry Olton, Spacecraft Coordinator.

U.S. Air Force

Col. G. Breton, FLTSATCOM System Program Director Deputy for Space Communication Systems; Space & Missile Systems Organization.

Pre-launch preparations for FLTSATCOM-E.





Atlas Centaur 59 soared aloft from Pad B at Launch Complex 36 at 4:16 a.m., August 6, 1981, placing the fifth and last of a series of FLTSATCOM military communications satellites in a preliminary transfer orbit.

SBS-B

Launch Vehicle - Delta 3910, 35 meters (116 feet) long and 2.4 m (8 ft.) in diameter. Its first stage, 22.4 m (73.6 ft.) long, was powered by a Rocketdyne main engine. This liquid-fueled engine (kerosene and liquid oxygen) developed 912 kilonewtons (205,000 pounds) of thrust. Strapped onto the first stage were nine solid-fuel Castor IV motors, made by Thiokol. Each of these boosters was 9.1 m (30 ft.) long, 1 m (3.3 ft.) in diameter and developed 378 kN (85,000 lb.) of thrust.

The nozzles on four of the strap-on motors had a new tilt angle to give the motors more thrust in the direction of motion. In previous launch, all nine booster nozzles were tilted outward 11 degrees from vertical. For the SBS-B launch, the tilt of four was reduced to 7 degrees.

Delta's 4.9-m (16-ft.) second stage was powered by a TRW-201 motor, which was also liquid-fueled (Aerozene 50 and nitrogen tetroxide) and developed 43.8 kN (9,850 lb.) of thrust.

Spacecraft Description - The satellite was spin stabilized. The communications platform contained the antenna and the repeater was de-spun for precision pointing toward earth. High pointing accuracy was achieved by using radio frequency beacons, in lieu of earth sensors, as reference sources for N-S and E-W antenna pointing control.

Project Objectives - Satellite Business Systems was a domestic satellite system that provided advanced communications services, including all-digital integration of voice, data, and image traffic. The system supports private, dedicated network services as well as services based on shared use of facilities.

SBS, a partnership sponsored by Aetna Life and Casualty, COMSAT General Corporation, and IBM, filed applications with the Federal Communications Commission (FCC) in late 1975, seeking authority to construct a domestic satellite system to serve industry, government, and public-service organizations. In February 1977, these applications were approved, and the FCC authorized SBS to proceed toward establishment of the system.

The features of the SBS system concept included:

- Fully integrated voice, data, and image services.
- All digital transmission.
- RF operation in the 12 and 14 GHz bands.
- 5- and 7-meter customer-premises earth stations.
- Reduced dependence on terrestrial interconnecting facilities.
- Centralized system-management facilities.
- Time-division multiple access of satellite communications channels.

- Demand assignment of satellite capacity to earth stations and networks.

- Voice activity compression to provide efficient utilization of channel capacity (similar methods are planned for digital channels).

- Facilities to enable customers to dynamically control and manage the use of their networks.

Spacecraft Payload - The satellite contained one active and three spare wideband receivers and 10 communications channels, including 10 active and six spares.

The satellite antennas provided shaped beams to cover the contiguous 48 states. The antenna design utilized a dual-surface offset-parabolic antenna using separate receive and transmit multibeam field arrays. In the direction of maximum radiation, the antenna gain was approximately 35 dB at 12 GHz and at 14 GHz.

Project Results - Successfully launched by Kennedy Space Center, September 24, 1981. Performance of the two-stage Delta launch vehicle was nominal and placed the payload in a suborbital trajectory as planned. The Payload Assist Module (PAM-D), which was part of the payload, also performed nominally. The synchronous transfer orbital elements achieved, compared with the nominal expected, were as follows:

	Expected	Measured
Apogee (NM)	19,901 (36,818 km)	19,511 (36,095 km)*
Perigee (NM)	90 (166 km)	87 (161 km)
Inclination (degrees)	27.7	27.5

*The measured apogee was 390 NM low. The two-stage Delta 3910 contributed only 49 NM of that error while the PAM-D contributed the rest.

The satellite performed satisfactorily during the transfer orbit and the ABM was fired successfully at 6:57 p.m., EDT on September 26, 1981. The satellite was maneuvered to a position 97 degrees West Longitude above the equator and satellite status is satisfactory. This was the second SBS satellite and second PAM-D placed in orbit by NASA.

Major Participants -

NASA Headquarters

Dr. Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joesph B. Mahon, Director, Expendable Launch Vehicles; Peter Eaton, Manager, Delta Launch Vehicles; R. E. Smylie, Associate Administrator for Space Tracking and Data Systems.

Goddard Space Flight Center

A. Thomas Young, Director; John H. McElroy, Deputy Director; William C. Keathley, Director, Project Management; David W. Grimes, Depta Project Manager; William A. Russell, Jr., Deputy Delta Project Manager; Martin Sedlazek, Deputy Delta Project Manager-SSUS; Phillip B. Frustace, Delta Mission Integration Manager; Richard King, Network Operations Manager; Pat Mazur, Mission Support Manager.

Kennedy Space Center

Richard G. Smith, Director; Charles D. Gay, Director, Deployable Payloads Operations; Wayne L. McCall, Chief, Delta Operations Division; D. C. Sheppard, Chief, Automated Payloads Division; David Bragdon, Spacecraft Coordinator.

Satellite Business Systems

Robert C. Hall, President; Robert S. Cooper, Vice President, Engineering; Irv Dostic, Launch Program Director; Michael T. Lyons, Mission Director; Alphonse J. Smith, Spacecraft System Manager; William H. Comerford, PAM and Vehicle Manager; Anthony J. van Hover, Satellite Control Manager.

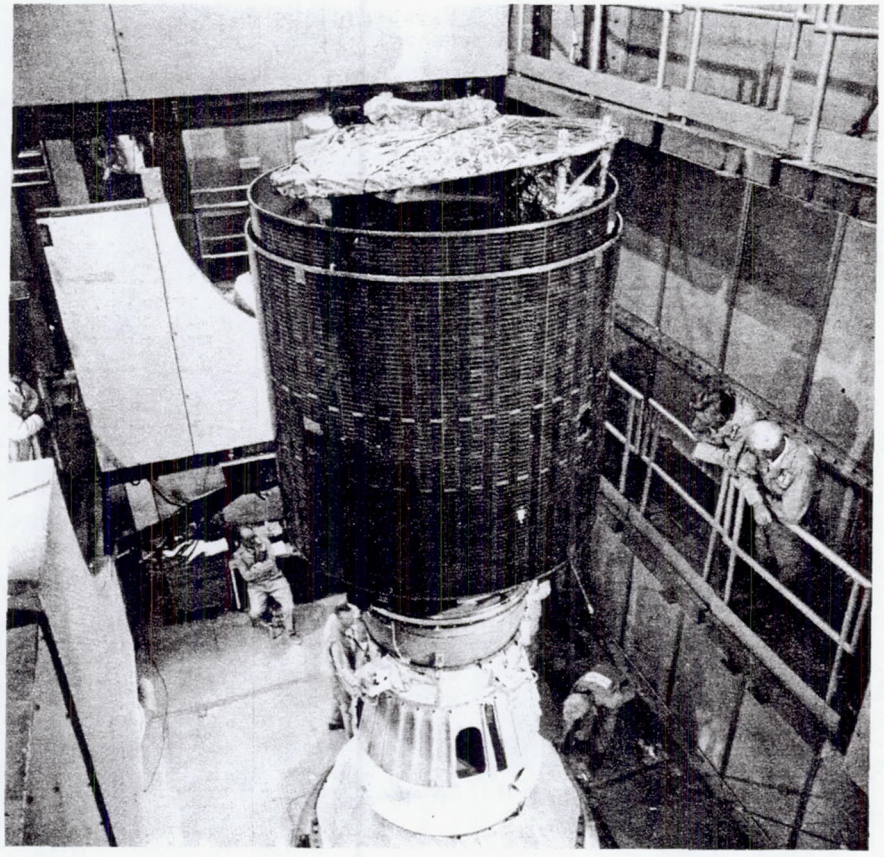
McDonnell Douglas Corp.

Lovis Rayburn, Delta Program Manager.

Hughes Aircraft Co.

W. B. Murray, SBS Project Manager.

Prior to spacecraft encapsulation, the SBS-B satellite and its payload assist module below were being inspected at Pad A, Launch Complex 17, Cape Canaveral Air Force Station.



SME/OSCAR 9

Launch Vehicle - Delta 156 from Vandenberg Air Force Base, California.

Spacecraft Description - The Solar Mesosphere Explorer satellite consisted of two major modules: the observatory module and the spacecraft bus. The satellite body was a cylinder 1.7 meters (69 inches) tall by 1.25 m (50 in.) in diameter. The spacecraft was powered by a disk-shaped solar array 2.2 m (88 in.) in diameter. The solar array was fixed to the lower end of the main cylinder, and charges nickel-cadmium batteries.

The satellite was spin-stabilized. A 5-rpm controlled spin rate stores angular momentum. Magnetic Torquing processed the spin axis to control roll error. The spin axis was maintained at right angles to the orbit plane. Yaw errors were sensed and corrected as roll error one-quarter of an orbit later. Horizon sensors measured roll error and spin rate, and a three-axis magnetometer provided Earth magnetic-field data to a closed-loop, control-law electronics set (attitude computer) for automatic roll and spin-rate control.

The instruments were opened and closed once each revolution to gather data as their field of view sweep toward the Earth's limb in the general altitude range of 80 km (50 mi.) to 20 km. (12 mi.) above the limb.

The UoSAT-OSCAR 9 Amateur Radio Scientific Satellite was launched into orbit as a piggyback payload with the Solar Mesosphere Explorer (SME) Mission. Orbital parameters are similar to those for the SME.

The spacecraft was checked out and evaluated by the project team at the University of Surrey in England. All spacecraft systems and experiments had been successfully exercised with the exception of the CCD camera and the gravity gradient boom.

Some difficulty was initially experienced commanding the spacecraft through the 145 MHz command receiver due to interference from the 145 MHz telemetry transmitter. This had been overcome by shifting to the redundant 435 MHz command system.

Project Objectives - The Solar Mesosphere Explorer was an atmospheric-research satellite designed to study reactions between sunlight, ozone, and other chemicals in the atmosphere and how concentrations of ozone are transported in the atmosphere in the region from 30 kilometers (19 miles) to 90 km (55 mi.) altitude.

Spacecraft Payload - Five scientific instruments aboard the SME satellite simultaneously monitored ozone and minor atmospheric-constituent quantities, water-vapor abundance and temperature, and the amount of incoming solar radiation to determine the role each plays in ozone production and distribution throughout the mesosphere. Scientific data from the mission was to help develop models for ozone production and depletion on a global scale.

. An ultraviolet ozone spectrometer, to measure ozone (0) between 40 km (25 mi.) and 70 km (43 mi.) altitude.

- A 1.27-micron spectrometer, to measure ozone between 50 km (31 mi.) and 90 km (56 mi.) altitude, and hydroxyl (OH) between 60 km (37 mi.) and 90 km (56 mi.) altitude.

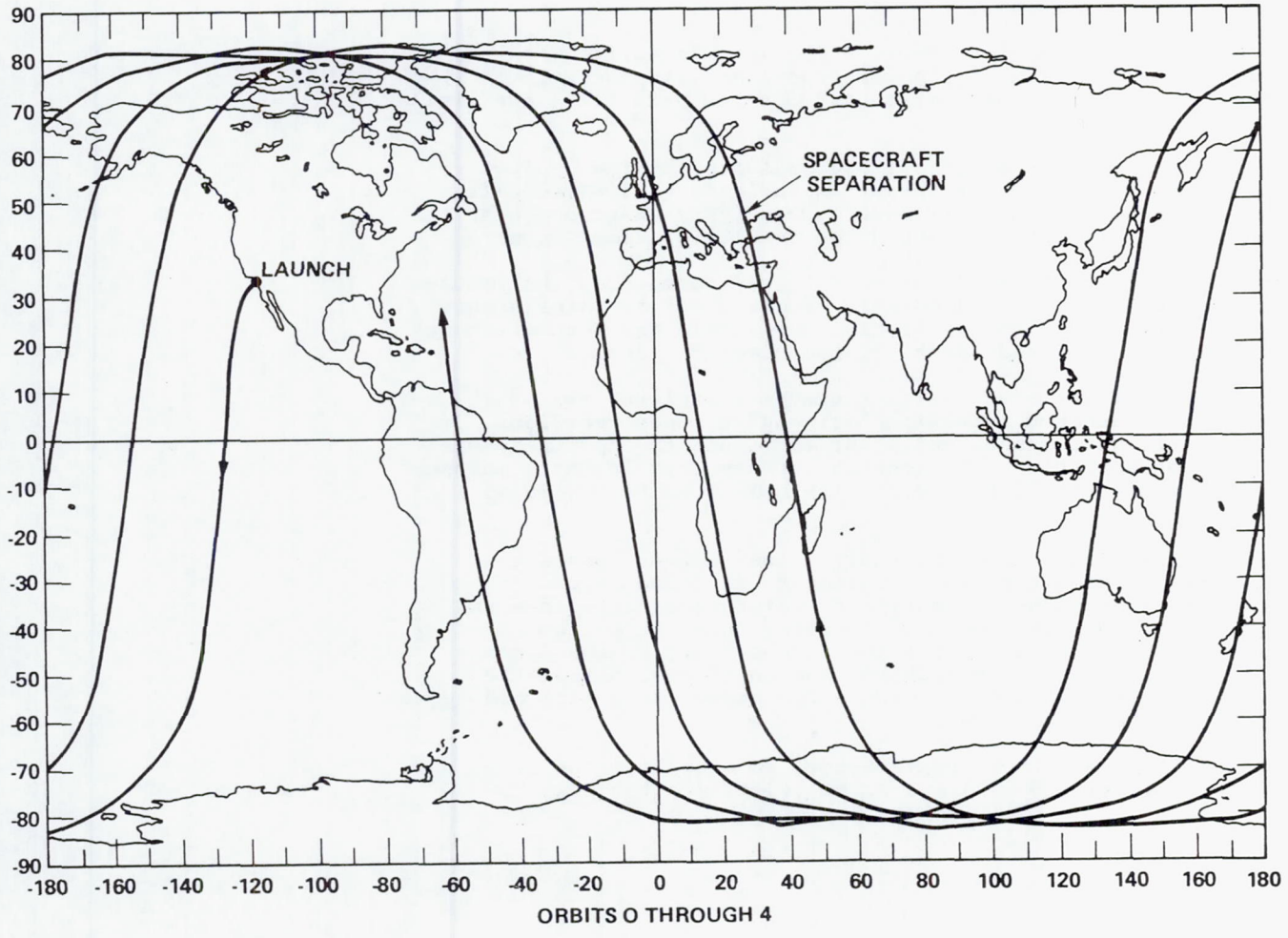
- A nitrogen dioxide spectrometer, to measure NO between 20 km (12 mi.) and 40 km (25 mi.) altitude.

- A four-channel infrared radiometer, to meaure temperature and pressure between 20 km (12 mi.) and 70 km (43 mi.) altitude; and water vapor and ozone between 30 km (19 mi.) and 65 km. (40 mi.) altitude.

- A solar ultraviolet monitor, to measure incoming radiation from the sun.

Project Results - Successfully launched from Vandenberg Air Force Base, California, on October 6, 1981. Orbital elements were 534 km apogee, 533 km perigee, with an inclination of 98.0 degrees and a period of 95.3 minutes.

TYPICAL SME GROUND TRACKS



Major Participants - The Jet Propulsion Laboratory, Pasadena, California, managed the Solar Mesosphere Explorer project for NASA's Office of Space Science. Ball Aerospace Systems Division provided the spacecraft bus, satellite integration and system test. The University of Colorado's Laboratory for Atmospheric and Space Physics was responsible for the science instruments, mission operations, the Project Operations Control Center and science data evaluation and dissemination was under contract to Jet Propulsion Laboratory. Members of the Jet Propulsion Laboratory included: Dr. Franklin D. Martin, Director, Solar Terrestrial and Astrophysics Division; J. Warren Keller, Deputy Director, Solar Terrestrial and Astrophysics Division; and Richard E. Halpern, Manager, Research Flight Programs Development.

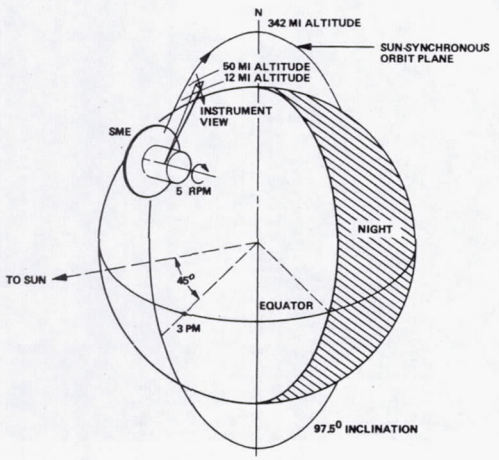
Kennedy Space Center

Richard G. Smith, Director; Thomas S. Walton, Director, Cargo Operations; Charles D. Gay, Director, Expendable Vehicles Operations Directorate; Wayne L. McCall, Chief, Delta Operations Division; Ray Kimlinger, Chief, Delta Western Operation Branch; E. J. Langenfeld, Spacecraft Coordinator, John Paulson, Project Manager; Dr. James Stuart, Deputy Project Manager; Kathleen Lee, Resources Documentation Control Manager.

Key Spacecraft Personnel		Affiliation
MG	M. B. Weinreb	NASA Headquarters
SC	S. G. Tilford	NASA Headquarters
PM	J. J. Paulson	NASA/JPL

Experiments	Experiment Personnel		Affiliation
U.V. Ozone,	PS	C. A. Barth	U. of Colorado
Infrared	PI	C. A. Barth	U. of Colorado
Radiometer,	OI	G. J. Rottman	U. of Colorado
1.27 Micron	OI	R. J. Thomas	U. of Colorado
Airglow,	OI	J. C. Gille	Natl Cntr for Atmos Res
Visible	OI	A. I. Stewart	U. of Colorado
Nitrogen	OI	C. W. Hord	U. of Colorado
Dioxide,	OI	P. J. Crutzen	Natl Cntr for Atmos Res
Solar UV	OI	R. E. Dickinson	Natl Cntr for Atmos Res
Monitor, and	OI	P. L. Bailey	Natl Cntr for Atmos Res
Solar Proton	OI	J. F. Noxon	NOAA
Alarm.	OI	G. E. Thomas	U. of Colorado
	OI	J. London	U. of Colorado

SME ORBIT GEOMETRY



STS-2

Program Overview, Launch Vehicle, Spacecraft I
see STS-1.

Project Objectives - This was the second in a
test flights to qualify the nation's new Space
System for routine space operations. First fl
Columbia was April 12-14, 1981.

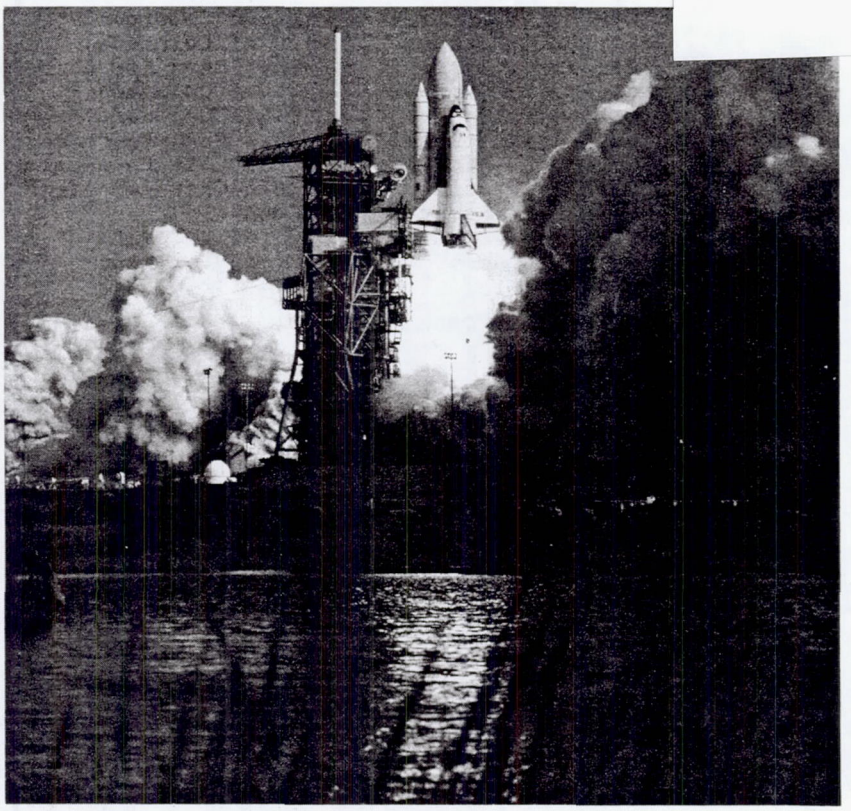
Joe H. Engle and Richard H. Truly were the cre
flight which had been scheduled for a duration
hours, and 10 minutes.

Neither of the astronauts had previously flown
although three of Engle's 16 flights in the ro
X-15 were above 80 kilometers (50 miles). Eng
flew the Orbiter Enterprise in two of the five
landing glide flights in 1977 in which the Orb
from a 747 aircraft.

On this second flight, the Orbiter carried the
and applictions payload to fly on the Shuttle
built remote manipulator arm which someday wil
deploy and retrieve space payloads.

STS-2 was to be launched into a 38-degree incli
circularized first at 222 km (120 nm) and later
253.7 km (137 nm) for the remainder of the flig
day was taken up with OSTA-1 and Orbiter system
tests of the payload bay door opening/closing m

The second flight day was to include checkout o
manipulator system in direct, manual, automatic
modes, and in activating and stowing the robot



STS-2 with Orbiter Columbia lifts off on its second voyage into space.

Day 3 was to include an airlock extravehicular activity demonstration in which Engle was to don a Shuttle spacesuit and walk through the EVA procedures, stopping just short of airlock depressurization. Data from remote manipulator arm operations was also to be evaluated.

Day 4 activities were to include an airlock extravehicular activity demonstration in which Engle was to don a Shuttle spacesuit and walk through the EVA procedures, stopping just short of airlock depressurization. Data from remote manipulator arm operations was also to be evaluated.

Day 4 activities was to deactivate OSTA-experiments and general clean-up, catch-up prior to entry day.

Before buttoning up the payload bay doors on entry day, Engle and Truly were to don the escape pressure suits, align Columbia's inertial measurement unit and prepare for the orbital maneuvering system deorbit maneuver which would bring Columbia back into the atmosphere to a landing on Rogers Dry Lake at Dryden Flight Research Center, Edwards, Calif. During final approach to Edwards, Columbia was to be guided automatically by the microwave scanning beam landing system on the lakebed down to flare, where the crew was to land manually.

One major objective for STS-2 was the evaluation of Columbia's ability to serve as a steady platform for Earth-viewing instruments. The OSTA-1 (Office of Space and Terrestrial Applications) package in the payload bay called for Columbia to be flown in an upside down position (-Z local vertical) for most of the flight. Except for activation, deactivation and occasional data takes, OSTA-1 experiments were largely automated and required little crew attention.

Another major operation was unloaded testing of the Canadian-built 15-meter (50 foot) long remote manipulator arm.

Spacecraft Payload - See above.

Project Results - Launched by Kennedy Space Center, Florida, on November 12, 1981. Shortly after launch, a problem developed in one of the three fuel cells that supplied electricity to Columbia. (Fuel cells produce electricity by chemically combining hydrogen and oxygen. In the process, water is produced as a byproduct.) The troubled fuel cell began registering an increase in acidity which indicated a possible blockage in the flow of hydrogen. To prevent a dangerous accumulation of hydrogen gas the cell was shut down. Although system redundancy onboard the Orbiter permitted it to return safely with only one fuel cell operating, mission controllers decided to bring the spacecraft home 3 days early. Many of the important tests scheduled for the Shuttle's second flight concerned Orbiter performance on reentry and landing. In the unlikely event of a second fuel cell failure, insufficient electrical power would have been available to perform those tests and land the Orbiter. Mission controllers made the decision to shorten the mission and insured the tests would take place. In spite of the shortened flight, between 90 and 95 percent of all test objectives were successfully met.

The craft landed at Edwards Air Force Base, California, on November 14, 1981, having completed 36 orbits. Duration of the mission was 54 hours, 13 minutes and 10 seconds.

Major Participants -

NASA Headquarters

L. Michael Weeks, Acting Associate Administrator for Space Transportation Systems; David R. Braunstein, Deputy Associate Administrator for Space Transportation Systems (Management); Daniel M. Germany, Director, Orbiter Programs; Walter F. Dankoff, Director, Engine Programs; Edward P. Andrews, Director, Ground Systems and Flight Test; LeRoy E. Day, Director, Systems Engineering and Integration; Frank Van Rensselear, Director, Upper Stage; and Jerry J. Fitts, Director, Solid Rocket Booster and External Tank.

Johnson Space Center

Glynn S. Lunney, Manager, Space Shuttle Program; Donald K. "Deke" Slayton, Manager, Orbital Flight Test; Aaron Cohen, Manager, Space Shuttle Orbiter Project Office; George W. S. Abbey, Director of Flight Operations; Maxime A. Faget, Director of Engineering and Development; Lynwood C. Dunseith, Director of Data Systems and Analysis.

Kennedy Space Center

Dr. Robert H. Gray, Manager, Shuttle Projects Office; John J. Neilon, Manager, Cargo Projects; George F. Page, Director, Shuttle Operations; Thomas S. Walton, Manager, Cargo Operations.

Marshall Space Flight Center

Robert E. Lindstrom, Manager, MSFC Shuttle Projects Office; James E. Kingsbury, Director, Science and Engineering Directorate; James B. Odom, Manager, External Tank Project; George B. Hardy, Manager, Solid Rocket Booster Project; James R. Thompson, Jr., Manager, Space Shuttle Main Engine Project; James M. Sisson, Manager, Engineering and Major Test Management Office.

Dryden Flight Research Center

John A. Manke, Chief of Flight Operations; Mel Burke, Shuttle Project Manager.

Goddard Space Flight Center

A. Thomas Young, Director, Dr. John H. McElroy, Deputy Director; Richard S. Sade, Director of Networks, Space Tracking and Data Network; Walter LaFleur, Deputy Director of Networks (STDN); William B. Dickinson, Chief, NASA Communications Network; Donald D. Wilson, Assistant Chief, NASA Communications Network; Daniel Spintman, Chief, Netowrk Operations Division; and James M. Stevens, Shuttle Network Support Manager.

Launch Vehicle - Delta 3910 launch vehicle consisted of a 2.4 meter (8 foot) first stage powered by a Rocketdyne RS-27 liquid-fueled engine; nine Thiokol Castor IV strap-on solid motors; a 1.5-m (5-foot) diameter second stage powered by a TRW TR-201 liquid fueled engine; and a 2.4 meter (8 ft.) diameter fairing.

Spacecraft Description - With solar panels deployed, the satellite spanned 11.2 meters (37 feet). The spacecraft main body measured 1.6 by 1.27 by 1.29 meters (64 by 50 by 51 in.). Its weight was 2,385 pounds.

The three-axis stabilized spacecraft was equipped with the power, attitude control, thermal control, propulsion, structure and command, ranging and telemetry necessary to support mission operations from booster separation through 10 years in geosynchronous orbit.

Project Objective - The RCA Domestic Communications Satellite (RCA Satcom III-R) was a 24-channel spacecraft to provide commercial communications to Alaska, Hawaii and the contiguous 48 states. RCA Satcom III-R was to distribute programming to the nation's cable television systems.

Spacecraft Payload - The RCA 24-channel communication satellite consisted of a fixed, four-reflector antenna assembly and a lightweight transponder of high-efficiency traveling-wavetube amplifiers and low-density microwave filters. Graphite-fiber epoxy-composite was the basic material for the 24 input and output multiplex filters, as well as for waveguide sections and antenna feeds.

Both horizontal and vertical polarizations were used in the communications subsystem for adjacent channel isolation. The communications antennas used grid reflectors allowing overlap of the horizontal and vertical reflector structures by positioning their grids perpendicular to each other. The transfer orbit omni antenna was attached to the communications antenna feedhorn support structure with its axis of symmetry along the spacecraft's transfer orbit spin axis. The synchronous orbit omni antenna was mounted on the antenna panel proper.

Project Results - Launched successfully from the Eastern Space and Missile Center (ESMC) at 8:37 p.m., EST, on November 19, 1981, by a Delta 3910 vehicle, mission number 158.

Performance of the two-stage Delta launch vehicle was nominal and placed the payload in a suborbital trajectory as planned. The payload Assist Module (PAM-D) which was part of the payload, also performed nominally. The Synchronous transfer orbital elements achieved, compared with the nominal expected, are as follows:

	Expected	Measured
Apogee (NM)	192,442 (35,967 km)	19,356 (35,809 km)*
Perigee (NM)	100 (185 km)	100 (185 km)
Inclination (degrees)	27.4	27.5

* The measured apogee was 86 NM low. The two-stage Delta 3910 contributed only 36 NM of that error while the PAM-D contributed the rest.

The satellite performed satisfactorily during the transfer orbit and the ABM was fired successfully at 5:30 p.m. EST on November 22, 1981. The satellite was maneuvered to a position 132 degrees West Longitude above the equator and satellite status is satisfactory. This was the fifth RCA satellite and third PAM-D placed in orbit by NASA.

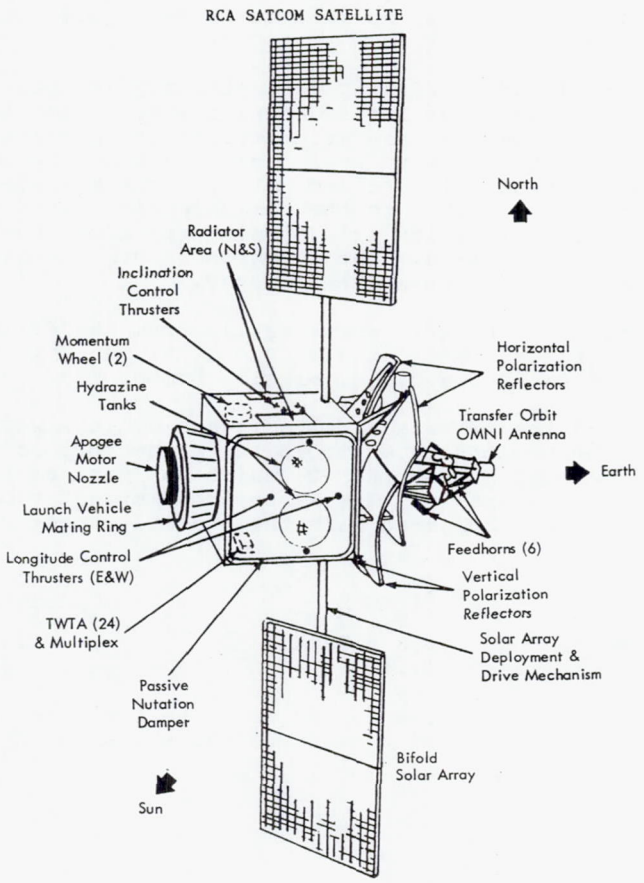
Major Participants -

NASA Headquarters

Dr. Stanley I. Weiss, Associate Administrator for Space Transportation Operations; Joseph B. Mahon, Director, Expendable Launch Vehicle Program; Peter Eaton, Manager, Delta; R. E. Smylie, Associate Administrator for Space Tracking and Data Systems.

Goddard Space Flight Center

A. Thomas Young, Director; John H. McElroy, Deputy Director; William C. Keathley, Director, Project Management; David W. Grimes, Delta Project Manager; William R. Russell, Deputy Delta Project Manager, Technical; John D. Kraft, Manager, Delta Mission Analysis and Integration; Richard H. Sclafford, RCA Satcom-D Mission Integration Manager; Richard S. King, Mission Operations and Network Support Manager; and Ray Mazur, Mission Support.



Kennedy Space Center

Richard G. Smith, Director; Thomas S. Walton, Director, Cargo Operations; Charles D. Gay, Director, Expendable Vehicles Operations; D. C. Sheppard, Chief, Automated Payloads Divison; Wayne McCall, Chief, Delta Operations Division; and David C. Bragdon, Spacecraft Coordinator.

RCA American Communications, Inc.

John Christopher, Vice President of Technical Operations; Peter Plush, Manager, Major Programs and Technical Operations Services; Joseph Schwarze, Manager, Space Systems; William Palme, Manager, Major Programs, Launch Vehicle Integration; and Joseph Elko, Manager, Spacecraft Engineering.

Contractors

RCA Americom, RCA Astro Electronics Division, Princeton, N.J., Spacecraft management development/production; McDonnell Douglas Astronautics Company, Huntington Beach, Calif., Delta Launch Vehicle and PAM-D payload stage; Rocketdyne Division, Rockwell International, Canoga Park, Calif., First stage engine (RS-27); Thiokol Corp., Huntsville, Ala., Castor IV strap-on solid fuel motors; TRW, Redondo Beach, Calif., TR-201 second stage engine.

Major Subcontractors

SPAR Aerospace Division, Ste-Anne-de-Bellevue, Quebec, Canada, Antenna Input and Output; Charles Stark Draper Labs, Cambridge, Mass., Momentum Wheel Assembly; Lockheed Space Systems Division, Sunnyvale, Calif., Earth Sensor Assembly and Horizon Sensor Assembly; Thiokol Corp., Elkton, Md., Apogee Kick Motor (Star 30) in spacecraft and Perigee Kick Motor (Star 48) in PAM-D; Hughes Aircraft Co., Electro Dynamics Division, Torrance, Calif., Amplifiers; Rocket Research, Redmond, Wash., Reaction Engine Assembly; Cubic Corp., Defense Systems Division, San Diego, Calif., Beacon Transmitter and Command Receiver; Parsons of California, Stockton, Calif., Structure and Solar Panels; Adcole Corp., Waltham, Mass., Sun Sensor Assembly; Northrop Corp., Norwood, Mass., Rate Measuring Assembly.

INTELSAT V-C

Launch Vehicle - INTELSAT V-C was launched by the Atlas Centaur, NASA's standard launch vehicle for intermediate weight payloads. The launch vehicle had the following general characteristics: height: 40.8 meters (134 feet) including nose fairing; diameter: 3.05 meters (10 feet); total liftoff weight: 147,926 kg (326,120 lbs.) including spacecraft; and liftoff thrust: 1,917,088 newtons (431,000 lb.) sea level.

Spacecraft Description - The spacecraft was 15.9 meters (52 feet) long and 6.4 meters (21 feet) wide in orbit. Other pertinent details were:

Dimensions--solar array (end to end), 15.6 meters (51.1 feet); main body "box," 1.66 x 2.01 x 1.77 meters (5.4 x 6.6 x 5.8 feet); height, 6.4 meters (21.0 feet); width (fully deployed), 6.8 meters (22.25 feet); and weight (at launch, without MCS), 1,928 kilos (4,251 pounds).

General Characteristics--Three-axis body stabilized with Sun and Earth sensors and momentum wheel; wing-like, Sun-oriented solar array panels producing a total of 1,241 watts of electrical power after 7 years in orbit; modular construction.

Project Objectives - The INTELSAT global satellite system comprised two essential elements: the space segment, consisting of satellites owned by INTELSAT, and the ground segment, consisting of Earth stations, owned by telecommunications entities in the countries in which they are located.

At launch time the space segment consisted of 10 satellites in synchronous orbit at an altitude of approximately 35,780 km (22,240 miles). Global service was provided through a combination of INTELSAT IV-A and INTELSAT IV satellites over the Atlantic, Indian, and Pacific Ocean regions.

The INTELSAT IV-A had a capacity of 6,000 voice circuits and two television channels, while the INTELSAT IV had a capacity of 4,000 voice circuits plus two television channels. The INTELSAT V had a capacity of 12,000 voice circuits plus two television channels.

The ground segment of the global system consisted of 295 communications antennas at 242 Earth station sites in 129 countries and territories.

The combined system of satellites and Earth stations provided more than 800 Earth station-to-Earth station communications pathways.

In addition to the international voice circuits in full-time use (now about 8,500), INTELSAT provided a wide variety of telecommunications services, including telegraph, telex, data, and television to over 150 countries, territories, and possessions.

Spacecraft Payload - INTELSAT IV-A made limited use of zonal beam antennas to increase its capacity by reusing frequencies twice. Of the 500 MHz bandwidth available to Intelsat IV-A, a portion was allocated to global coverage transmissions and

the remaining bandwidth was used twice in two hemispherical beams which were concentrated over heavy traffic areas. As these beams did not overlap, except with the global coverage beam, there was no possibility of signals in one beam interfering with signals in the other, even though they were on the same frequencies.

With INTELSAT V, frequency reuse techniques had been taken even further with the introduction of polarized transmissions. Overlaid on INTELSAT V's global beam transmissions were two circularly polarized transmissions beamed into separate hemispheres. Overlaid upon each of these, using the same frequencies but polarized in the opposite directions (orthogonal to the hemisphere transmissions), were two zonal beam transmissions. All of these beams used and reused the frequencies in the 6/4 GHz band. In addition, there were concentrated spot beam transmissions using, for the first time for INTELSAT, frequencies in the 14/11 GHz band.

Project Results - INTELSAT V-C (F-3), the third of the INTELSAT V series, was successfully placed into the desired transfer orbit by Atlas Centaur vehicle AC-55, meeting all NASA objectives. The satellite was launched from Complex 36, Cape Canaveral, Florida, at 6:35 p.m., EST, on December 15, 1981.

	Planned	Actual
Apogee (km)	35,964	35,953
Perigee (km)	166.6	165.8
Inclination (degrees)	23.697	23.697
Eccentricity	.73225	.73222

The apogee kick motor was fired successfully by COMSAT on December 18, placing the satellite into near geosynchronous orbit. After initial positioning for preliminary testing, the satellite was moved to be on-station at 335.5 degrees East longitude.

Major Participants -

INTELSAT

Andrea Caruso, Deputy Director General-Administration; Francis Latapie, Acting Deputy Director General-Administration; Allan M. McCaskill, Manager, Launch Vehicle Program Office.

NASA Headquarters

Stanley I. Weiss, Associate Administrator for Space Transportation Operations; J. B. Mahon, Director, Expendable Launch Vehicles; F. R. Schmidt, Atlas-Centaur Manager.

Lewis Research Center

James E. Patterson, Director, Launch Vehicles; Richard E. Orzechowski, Mission Project Engineer.

Kennedy Space Center

Charles D. Gay, Director, Expendable Vehicles Operations; Donald G. Sheppard, Chief, Automated Payloads Division; Larry F. Kruse, Intelsat Spacecraft Coordinator.

Contractors

Ford Aerospace and Communications Corporation, Palo Alto, Calif., Intelsat V Spacecraft; General Dynamics/Convair, San Diego, Calif., Atlas-Centaur Vehicle; Honeywell, Aerospace Division, St. Petersburg, Fla., Centaur Guidance Inertial Measurement Group; Pratt and Whitney, West Palm Beach, Fla., Centaur RL-10 Engines; and Teledyne Systems Co., Northridge, Calif., Digital Computer Unit/PCM Telemetry.

NASA Launch Record
1958 - 1981

NASA Major Launch Record

1958

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Pioneer I Eta 1	Thor- Able I	11 Oct	12 Oct 58		113,783			38.28	Particles and Fields: Radial extent of radiation bands; hydromagnetic oscillation. Failed to reach moon; sent 43 hrs of data.
Beacon I Suborb	Jupiter C	23 Oct	23 Oct 58					4.20	Atmospheric Physics: 12-foot sphere; upper stages separated *prior to burnout*.
Pioneer II Suborb	Thor- Able I	8 Nov	8 Nov 58					39.19	Scientific Lunar Probe: Third-stage failure; reached 963 miles; its brief data indicated equatorial region had higher flux and energy levels than previously thought.
Pioneer III Theta 1	Juno II	6 Dec	7 Dec 58		102,300			5.87	Energetic Particles: Discovered second radiation belt. Failed to reach moon.

1 lb = 0.4536 kg 1 mi = 1.609 km 1 NM = 1.8515 km

NASA Major Launch Record

1959

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Vanguard II Alpha 1	Vanguard (SLV-4)	17 Feb		124.9	3243	556	32.8	9.4	Meteorology: Precession of satellite prevented usable cloud cover data. First Earth photo from satellite.
Pioneer IV Nu 1	Juno II	3 Mar		HELIOCENTRIC ORBIT				6.07	Cislunar and Lunar Probe: Energetic particles, passed 37,300 miles from the moon on 4 Mar 59.
Vanguard Suborb	Vanguard (SLV-5)	13 Apr	13 Apr 59					10.56	Magnetic Fields and Atmospheric Physics: 30-inch sphere; second-stage failure.
Vanguard Suborb	Vanguard (SLV-6)	22 Jun	22 Jun 59					10.20	Solar-Earth Heating: Second-stage failure.
Explorer (S-1) Suborb	Juno II	16 Jul	16 Jul 59					41.50	Energetic Particles: Destroyed after 5-1/2 seconds by range safety officer.
Explorer VI (S-2) Delta 1	Thor-Able	7 Aug	Prior to July 61	768	42,412	252	47.0	64.41	Particles and Meteorology: Three radiation levels; crude cloud cover image; ring of electric current circling earth.
Beacon II Suborb	Juno II	14 Aug	14 Aug 59					4.53	Atmospheric Physics: 12-foot sphere; premature fuel depletion in first stage; upper-stage malfunction.
Big Joe (Mercury) Suborb	Atlas	9 Sep	9 Sep 59						Suborbital Mercury Capsule Test: Capsule successfully recovered after reentry test.

1 lb = 0.4536 kg 1 mi = 1.609 km 1 NM = 1.8515 km

NASA Major Launch Record

1959

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Vanguard III Eta 1	Vanguard (SLV-7)	18 Sep		129.1	3659	511	33.3	45.36	Particles and Fields: Magnetic field survey, lower edge of radiation belt. Last transmission 8 Dec 59.
Little Joe 1 Suborb	Little Joe (L/V #6)	4 Oct	4 Oct 59						Suborbital Mercury Capsule Test: Qualified booster for use with Mercury test program. (WI)
Explorer VII (S-1δ)/Iota 1	Juno II (19A)	13 Oct		100.7	1041	548	50.3	41.5	Energetic Particles: Data on radiation and magnetic storms; first micrometeorite penetration of sensor.
Little Joe 2 Suborb	Little Joe (L/V #1A)	4 Nov	4 Nov 59						Suborbital Mercury Capsule Test: Capsule escape test. Escape rocket had a delayed thrust buildup. (WI)
Pioneer (P-3) Suborb	Atlas-Able	26 Nov	26 Nov 59					168.74	Lunar Orbiter: Shroud failure after 45 seconds.
Little Joe 3 Suborb	Little Joe (L/V #2)	4 Dec	4 Dec 59						Suborbital Mercury Capsule Test: Escape system and biomedical tests; Monkey (Sam) (High altitude abort demonstration at max. q). (WI)
1960									1960
Little Joe 4 Suborb	Little Joe (L/V #1B)	21 Jan	21 Jan 60						Suborbital Mercury Capsule Test: Escape system and biomedical test; Monkey (Miss Sam) aboard. (WI)
Pioneer V (P-2) Alpha 1	Thor- Able IV	11 Mar			.995 AU	.8061 AU	3.35	43	Particles and Fields: Ciscytherean space; first solar flare data; solar wind.
					HELIOCENTRIC ORBIT				

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NASA Major Launch Record

1960

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Explorer (S-46) Suborb	Juno II	23 Mar	23 Mar 60					16.01	Energetic Particles: Failure in upper stages.
Tiros 1 Beta 2	Thor-Able	1 Apr		99.0	738	689	48.3	122.47	Meteorology: First global cloud cover pictures. Last transmission 17 Jun 60.
Scout X Suborb	Scout X	18 Apr	18 Apr 60						Launch Vehicle Development Test: Structural failure prevented third-stage ignition (dummy second and fourth stages); (WI)
Echo A-10 Suborb	Thor- Delta	13 May	13 May 60					56.24	Communications Earth Satellite: Failure in upper stages of vehicle.
Scout I Suborb	Scout	1 Jul	1 Jul 60						Launch Vehicle Development Test. (WI)
Mercury (MA-1) Suborb	Atlas	29 Jul	29 Jul 60						Suborbital Mercury Capsule Reentry Test: Atlas exploded.
Echo I (A-11) Iota 1	Thor- Delta	12 Aug	24 May 68	118.2	1692	1514	47.2	56.24	Communications Earth Satellite: First passive communications satellite. 100-foot sphere used for passive communication and air density experiments.
Pioneer (P-30) Suborb	Atlas-Able	25 Sep	25 Sep 60					175.54	Scientific Lunar Orbiter: Second-stage failure.

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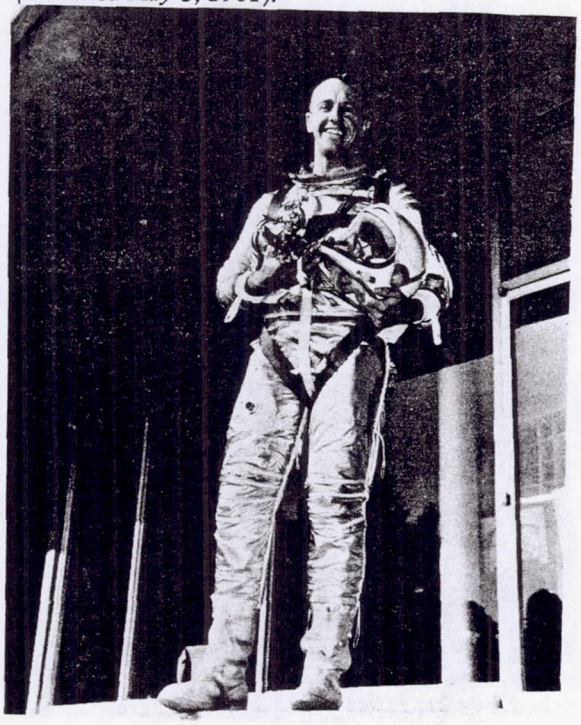
MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Scout II Suborb	Scout	4 Oct	4 Oct 60						Launch Vehicle Development Test: Air Force Special Weapons Center radiation experiment payload included. (WI)
Explorer VIII (S-30)/ Xi 1	Juno II	3 Nov		112.7	2287	458	50.0	40.88	Ionosphere: Confirmed existence of helium layer in upper atmosphere. Last transmission 28 Dec 60.
Little Joe 5 Suborb	Little Joe (L/V #5)	8 Nov	8 Nov 60						Suborbital Mercury Capsule Test: Mercury capsule system qualification; premature escape-rocket firing. (WI)
Tiros II Pi 1	Thor-Delta	23 Nov		98.3	727	622	48.5	127	Meteorology: Optical and infrared photos of global cloud cover.
Explorer (S-56) Suborb	Scout	4 Dec	4 Dec 60					6.35	Atmospheric Physics/Vehicle Test: 12-foot sphere; second-stage failure. (WI)
Pioneer (P-31) Suborb	Atlas-Able	15 Dec	15 Dec 60					175.9	Scientific Lunar Orbiter: Exploded after 74 seconds.
Mercury (MR-1A) Suborb	Redstone	19 Dec	19 Dec 60						Suborbital Mercury Capsule Test: Unmanned 235-mile flight. Successful.
1961									1961
Mercury (MR-2) Suborb	Redstone	31 Jan	31 Jan 61					1315	Suborbital Mercury Capsule Test: 16-minute flight of chimpanzee (Ham)

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Explorer IX (S-56a)/Delta 1	Scout	16 Feb	9 Apr 64	118.3	2583	634	38.6	6.80	Atmospheric Physics/Vehicle Test: 12-foot sphere. (WI)
Mercury (MA-2) Suborb	Atlas	21 Feb	21 Feb 61					1315	Suborbital Mercury Capsule Test: Unmanned; 1425-mile flight; successful.
Explorer (S-45) Suborb	Juno II	24 Feb	24 Feb 61					32.65	Ionosphere: Second-stage malfunction prevented third- and fourth-stage firing.
Little Joe 5A Suborb	Little Joe (L/V #5A)	18 Mar	18 Mar 61					1315	Suborbital Mercury Capsule Test: Mercury escape system qualification; premature escape-rocket firing. (WI)
Mercury (MR-BD) Suborb	Redstone	24 Mar	24 Mar 61					1315	Vehicle Test for Mercury Flight: Booster development test necessitated by MR-2 flight results.
Explorer X (P-14) Kappa 1	Thor-Delta	25 Mar	Jun 68	6720	233,305	160	33.9	35.83	Particles and Fields: Interplanetary magnetic field near earth, mainly extension of sun's magnetic field.
Mercury (MA-3) Suborb	Atlas	25 Apr	25 Apr 61					907.2	Orbital Mercury Capsule Test: Failure in first stage; abort successful.
Explorer XI (S-15)/ Nu 1	Juno II (4 stages)	27 Apr		108.1	1719	483	28.8	37.19	Gamma-Ray Astronomy: Eliminated simultaneous matter-antimatter creation theory of steady-state cosmology. Last transmission 7 Dec 61.

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Astronaut Alan B. Shepard, Jr., Freedom 7 (launched May 5, 1961).



NASA Major Launch Record

1961

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Little Joe 5B Suborb	Little Joe (L/V #5B)	28 Apr	28 Apr 61					1315	Suborbital Mercury Capsule Test: One booster engine fired late. Repeat of Mercury escape system test. (WI)
Mercury (Freedom 7) Suborb	Mercury-Redstone-3	5 May	5 May 61					1315	Manned Suborbital: Alan B. Shepard, Jr. 15 minutes flight time.
Explorer (S-45a) Suborb	Juno II	24 May	24 May 61					34.02	Ionosphere: Second-stage failure
Meteoroid Satellite A (S-55) Suborb	Scout	30 Jun	30 Jun 61					84.82	Micrometeoroids/Vehicle Test: Third-stage failure. (WI)
Tiros III Rho 1	Thor-Delta	12 Jul		100.3	814	741	47.8	129	Meteorology: Good cloud cover picture, infrared data. Last transmission 27 Feb 62.
Liberty Bell 7 Suborb	Mercury-Redstone-4	21 Jul	21 Jul 61					1315	Manned Suborbital: Virgil I. Grissom. 16 minutes flight time.
Explorer XII (S-3) Upsilon 1	Thor-Delta	16 Aug	Sep 63	1585	77,232	292	33.3	37.64	Particles and Fields: Identified Van Allen Belt as a magnetosphere.
Ranger I Phi 1	Atlas-Agena	23 Aug	30 Aug 61	91.1	503	168	32.9	306.18	Particles and Fields: Lower earth orbit than planned.

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Launch Record



Astronaut Virgil I. Grissom, Liberty Bell 7 (launched July 21, 1961).

NASA Major Launch Record

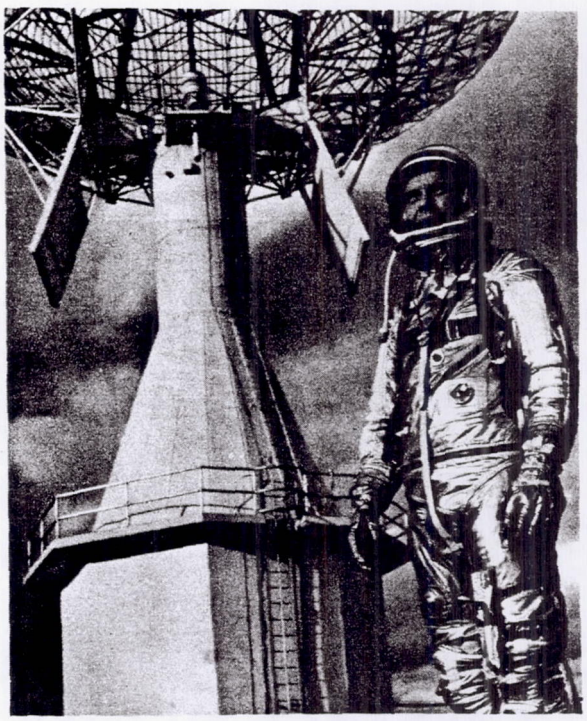
1961

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Explorer XIII (S-55a)/ Chi 1	Scout	25 Aug	28 Aug 61	97.3	975	281	36.4	84.82	Micrometeoroids/Vehicle Test: Premature reentry after three days. (WI)
Mercury (MA-4) A-Alpha 1	Atlas	13 Sep	13 Sep 61	88.6	255	160	32.6	1224.72	To orbit the unmanned Mercury capsule to test systems and ability to return capsule to predetermined recovery area after one orbit. All capsule tracking and recovery objectives met.
Probe A (P-21) Suborb	Scout	19 Oct	19 Oct 61						Scientific Geoprobe/Vehicle Test: Reached 4261 miles. Electron density measurement; vehicle test. (WI)
Saturn Test (SA-1)/ Suborb	Saturn I	27 Oct	27 Oct 61						Launch Vehicle Development: Test of propulsion system of the booster (S-I); verification of aerodynamic and structural design of entire vehicle.
Mercury (MS-1) Suborb	AF 609A (Blue Scout)	1 Nov	1 Nov 61					68.04	Orbital Mercury Network Check: Destroyed after 30 seconds; Air Force launched.
Ranger II A-Theta 1	Atlas-Agena	18 Nov	20 Nov 61	88.28	236	157	33.3	306.18	Particles and Fields: Agena failed to restart.
Mercury (MA-5) A-Iota 1	Atlas	29 Nov	29 Nov 61	88.3	238	160	32.5	1315.44	Mercury Orbital Flight: Chimpanzee Enos aboard. Recovered after two orbits.

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Echo (AVT-1) Suborb	Thor	15 Jan	15 Jan 62					256	Suborbital Communications Test: Canister ejection and opening successful but 135-foot sphere ruptured.
Ranger III (P-34) Alpha 1	Atlas-Agena	26 Jan		HELIOCENTRIC ORBIT				329.76	Lunar Exploration: TV pictures, hard instrument landing planned; second stage of Agena failed; spacecraft missed the moon by 22,862 miles on 28 Jan 62. TV pictures unusable.
Tiros IV Beta 1	Thor-Delta	8 Feb		100.4	844	709	48.3	129	Meteorology: Supported Friendship 7 flight. Transmitted cloud cover photos to 10 Jun 62.
Mercury (MA-6) (Friendship 7) Gamma 7	Atlas	20 Feb	20 Feb 62	88.5	262	160	32.5	1315.44	Manned: John H. Glenn, Jr.; three orbits. First manned orbital flight by US. 4 hrs 55 mins.
Reentry 1	Scout	1 Mar	1 Mar 62						Launch Vehicle Development; Reentry: Desired speed not achieved. (WI)
OSO-1 Zeta 1	Thor-Delta	7 Mar		95.2	595	553	32.8	199.58	Solar Physics: Provided data on approximately 75 solar flares. Last transmission 6 Aug 63.
Probe B (P-21a) Suborb	Scout	29 Mar	29 Mar 62						Scientific Geoprobe: Electron density measurements; reached 3910 miles. (WI)
Ranger IV Mu 1	Atlas-Agena	23 Apr	26 Apr 62					331.12	Lunar Exploration: TV pictures not obtained; loss of control 2 hours after launch; first US lunar impact (Far side).

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Astronaut John H. Glenn, Jr., Friendship 7 (launched February 20, 1962).

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	
Saturn Test (SA-2)/Suborb	Saturn I	25 Apr	25 Apr 62					86,167	Launch Vehicle Test: Carried 95 tons of ballast water in upper stages released at an altitude of 65 miles in order to observe the effect on the upper region of the atmosphere ("Project High Water.")
Ariel I Omicron 1	Thor-Delta	26 Apr	24 May 76	95.9	770	361	53.8	59.87	Ionosphere: Investigated solar effects. First International Satellite. (United Kingdom Cooperative)
Centaur Test I (AC-1)/Suborb	Atlas-Centaur	8 May	8 May 62						Launch Vehicle Development Test: Centaur exploded before separation.
Aurora 7 (MA-7)/ Tau 1	Atlas	24 May	24 May 62	88.3	268	160	32.5	1349.46	Manned: M. Scott Carpenter; three orbits. 4 hrs 56 mins.
Tiros V A-Alpha 1	Thor-Delta	19 Jun		100.3	955	591	58.1	129.27	Meteorology: Infrared system inoperative; good cloud cover pictures. Last transmission 4 May 63.
Telstar I A-Epsilon 1	Thor-Delta	10 Jul		157.7	5642	944	44.8	77.11	Communications: First privately built satellite. First TV transmission. Last transmission 21 Feb 63. (Reimbursable)
Echo (AVT-2) Suborb	Thor	18 Jul	18 Jul 62					256	Suborbital Communications Test: Inflation successful; radar indicated sphere surface not as smooth as planned.
Mariner I (P-37) Suborb	Atlas-Agena	22 Jul	22 Jul 62					202.30	Scientific Venus Probe: Atlas deviated from course and was destroyed by Range Safety Officer.

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Astronaut M. Scott Carpenter, Aurora 7 (launched May 24, 1962).



Astronaut Walter M. Schirra, Sigma 7 (launched October 3, 1962).

NASA Major Launch Record

1962

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Mariner II (P-38) A-Rho 1	Atlas-Agena	27 Aug		HELIOCENTRIC ORBIT				202.75	Planetary Exploration: Venus; first successful interplanetary probe. Found no magnetic field; high surface temperatures of approximately 800°F. Passed Venus 14 Dec 62 at 21,648 miles, 109 days after launch.
Reentry II Suborb	Scout	31 Aug	31 Aug 62						Reentry Test (28,000 fps): Late third-stage ignition; desired speed not achieved. (WI)
Tiros VI A-Psi 1	Thor-Delta	18 Sep		98.5	698	684	58.3	127	Meteorology: Infrared sensor omitted. Last transmission 11 Oct 63.
Alouette I B-Alpha 1	Thor-Agena B	29 Sep		105.4	1032	999	80.4	145.15	Ionosphere: Radiation belt effects. Second International Satellite. (Cooperative with Canada)
Explorer XIV (S-3a) B-Gamma 1	Thor-Delta	2 Oct		2184	98,454	279	32.9	40.37	Particles and Fields: Data compared with that of Explorer XII. Last transmission 17 Feb 64.
Sigma 7 (MA-8) B-Delta 1	Altas	3 Oct	3 Oct 62	88.75	285	153	32.55	1369.87	Manned: Walter M. Schirra; 6 orbits. 9 hours 13 minutes.
Ranger V B-Eta 1	Atlas-Agena	18 Oct		HELIOCENTRIC ORBIT				342.46	Lunar Exploration: TV pictures, hard instrument landing planned. Power loss; 450 miles from moon 20 Oct 62; no TV pictures obtained.

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NASA Major Launch Record

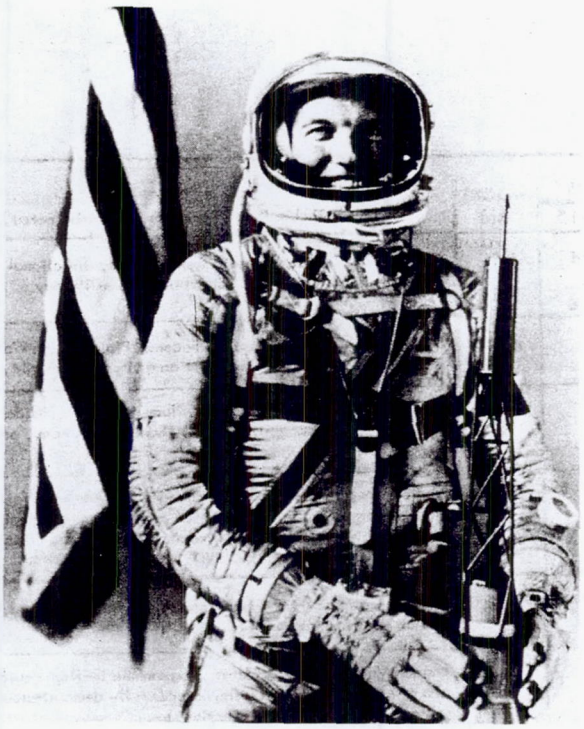
1962

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Explorer XV (S-3b) B-Lambda 1	Thor-Delta	27 Oct		Current Elements Not Maintained				45.36	Particles and Fields: De-spin system failed, directional detectors almost unusable. Last transmission 19 May 63.
Saturn (SA-3) Suborb	Saturn I	16 Nov	16 Nov 62					86,167	Launch Vehicle Development: Second "Project High Water" using 95 tons of water released at an altitude of 90 NM.
Relay I B-Upsilson 1	Thor-Delta	13 Dec		185	7437	1320	47.4	78.01	Communications: Initial power failure overcome. Wideband transmission; TV capability of 300 channel telephony, one way. Last transmission Feb 65.
Explorer XVI (S-55b) B-Chi 1	Scout	16 Dec		104.3	1177	747	51.9	100.69	Micrometeoroids: First statistical sample; flux level found to lie between estimated extremes; 64 penetrations of sample materials over useful life of 7 months. Sensor area 30 sq. ft. Last transmission 22 Jul 63. (WI)
1963									1963
Syncom I 1963 4A	Thor-Delta	14 Feb		1,426.6	36,931	34,102	33.5	39	Communications: First synchronous-type orbit. Radio contact lost at insertion into orbit.
				GEOSYNCHRONOUS ORBIT					
Saturn Test (SA-4) Suborb	Saturn I	28 Mar	28 Mar 63						Launch Vehicle Development: Programmed in-flight cutoff of one of eight engines in cluster; successfully demonstrated propellant utilization system function.
Explorer XVII (S-6)/1963 9A	Thor-Delta	3 Apr	24 Nov 66	96.4	913	254	57.6	184.61	Aeronomy: Discovered belt of neutral helium atoms about earth. Ceased transmitting experiment data 10 Jul 63.

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Telstar II 1963 13A	Thor-Delta	7 May		225.2	10,800	971	42.7	79.38	Communications satellite. Last transmission May 65. (Reimbursable)
Mercury (Faith 7) 1963 15A	Atlas MA-9	15 May	16 May63	88.5	267	161	32.54	1,369.87	Manned: L. Gordon Cooper; 22 orbits. Oriented manually for reentry. 34 hours 20 minutes.
RFD-1	Scout	22 May	22 May63	SUBORBITAL FLIGHT				217.6	AEC Reactor Mockup Reentry Flight (Reimbursable)
Tiros VII 1963 24A	Thor-Delta	19 Jun		97.1	630	612	58.2	134.71	Meteorology. Last transmission 3 Feb 66.
CRL (USAF) 1963 26A	Scout	28 Jun		99.6	1,074	405	49.7	118	Cambridge Research Lab - Geophysics (Reimbursable)
Reentry III Suborb	Scout	20 Jul	20 Jul 63	VEHICLE FAILED					Reentry Flight Demonstration: Attempted test of an ablation material at super-orbital reentry speeds. (WI)
Syncom II 1963 31A	Thor-Delta	26 Jul		GEOSYNCHRONOUS ORBIT				38.55	Communications: First operational satellite in a synchronous type orbit.
Little Joe II Test Suborb	Little Joe II #1	28 Aug	28 Aug63						Suborbital Apollo Launch Vehicle Test: Booster qualification test with dummy payload. (White Sands Missile Test Range)
Explorer XVIII (IMP-A) 1963 46A	Delta (DSV-3C)	27 Nov	Dec 65	5778	197,137	192	33.3	62.59	Particles and Fields: Highly elliptical orbit. Confirmed existence of solar wind shock wave on magnetosphere. First Delta with X-258 third stage. Last transmission 12 May 65.

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Astronaut L. Gordon Cooper, Jr., Faith 7 (launched May 15, 1963).

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Centaur Test II (AC-2) 1963 47A	Atlas-Centaur	27 Nov		107.1	1717	472	30.3	4,620.8	Vehicle Development: Instrumented with 2000 lbs of sensors, equipment, and telemetry.
Explorer XIX (AD-A) 1963 53A	Scout	19 Dec		112	1766	877	78.9	8.07	Atmospheric Physics: 12-foot diameter sphere (Explorer IX design); polar orbit. (WTR) Two (passive) experiments.
Tiros VIII 1963 54A	Delta (DSV-3B)	21 Dec		99.2	747	698	58.4	120.20	Meteorology: Carried Automatic Picture Transmission (APT) System; allowed real-time readout of local cloud pictures using an inexpensive portable ground station. Last transmission 1 Jul 67.
1964									1964
Relay II 1964 3A	Delta (DSV-3B)	21 Jan		194.7	7448	2050	46.3	83	Communications: Wideband transmission; TV capability or 300 channel telephone, one way. Last transmission 23 May 65.
Echo II 1964 4A	Thor-Agena	25 Jan	7 Jun 69	108.8	1312	1032.9	81.5	256	Communications: Rigidized 135-foot sphere; passive. (WTR)
Saturn I (SA-5) 1964 5A	Saturn I	29 Jan	30 Apr 66	94.8	757.8	263.8	31.5	17,100	Vehicle Development: Fifth flight of Saturn I; first Block II Saturn, first live flight of the LOX/LH_2 fueled second stage (S-IV). 1146 measurements taken.
Ranger VI 1964 7A	Atlas-Agena	30 Jan	2 Feb 64					364.6	Lunar Exploration: TV pictures prior to hard landing planned; lunar impact point within 20 statute miles of target on West edge of Sea of Tranquility; TV system failed to operate.

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Beacon Exp. A (S-66) Suborb	Delta (DSV-3B)	19 Mar	19 Mar 64					52.16	Ionosphere: Designed to advance the state-of-the-art of lasers for optical tracking and geodesy. Third stage (X-248) fired only half normal time; satellite failed to orbit. First Thor-Delta failure after 23 successes; last X-248 third stage.
Ariel II (UK) 1964 15A	Scout	27 Mar	18 Nov 67	101.3	1356.3	289.6	51.6	68.04	Planetary Atmosphere/Radio Astronomy: Continuation of the United Kingdom International Satellite program; first in program to sample global distribution of ozone with an ultraviolet spectrometer. (WI)
Gemini I 1964 18A	Titan II	8 Apr	12 Apr 64	89.2	328.2	160.9	32.6	3186.9	Space Vehicle Development: Demonstration of the launch vehicle and guidance systems, and structural integrity and compatibility of the spacecraft and launch vehicle. 132 measurements taken. Spacecraft was not equipped to separate from second stage. First in Gemini series.
Fire I Suborb	Atlas-X259	14 Apr	14 Apr 64						Reentry Test: Investigated the heating environment encountered by a body entering the earth's atmosphere at high speed. Actual reentry velocity: 37,963 fps.
Apollo Transonic Abort Suborb	Little Joe II	13 May	13 May 64						Apollo LES Development: Simulation of Apollo Launch Escape System where high dynamic pressures and transonic speed conditions exist. First launch of Apollo spacecraft boilerplate (White Sands Missile Range)

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Saturn I (SA-6) 1964 25A	Saturn I	28 May	1 Jun 64	88.5	225.26	199.5	31.8	17,645	Vehicle Development: Sixth flight of Saturn I; first flight of unmanned boilerplate model of Apollo. 1181 flight measurements taken.
Centaur Test III (AC-3) Suborb	Atlas-Centaur	30 Jun	30 Jun 64						Vehicle Development: All six primary objectives successful. Hydraulic pump failure caused short Centaur engine burn.
SERT-1 Suborb	Scout	20 Jul	20 Jul 64					170.1	Ion Engine Test: Ion beam neutralization in space verified. (WI)
Ranger VII 1964 41A	Atlas-Agena	28 Jul	31 Jul 64					365.6	Lunar Exploration (Photography): Camera system yielded 4316 high resolution TV pictures with about 2000 times better definition than present earth-based photography; objects less than 3 feet discernible. Impact occurred in Sea of Clouds region 8-10 miles from the aim point. 68 hours, 36 minutes.
Reentry IV (R-4) Suborb	Scout	18 Aug	18 Aug 64					145.15	Reentry Test: Demonstrated ability of one type of low density charring ablator material for Apollo to withstand reentry conditions at 27,950 fps. (WI)
Syncom III 1964 47A	TAD (DSV-3D)	19 Aug		1436.9	35,809	35,794	6.0	37.64	Communications: Third and last of the Syncom series
					GEOSYNCHRONOUS ORBIT				

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NASA Major Launch Record 1964

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Explorer XX (IE-A) (S-48) 1964 51A	Scout	25 Aug		103.8	1019	866	79.9	44.45	Ionosphere: Measurement of electron density distribution in the F_2 layer by topside sounding on six fixed frequencies. Last transmission 30 Mar 66. (WTR)
Nimbus I 1964 52A	Thor-Agena	28 Aug		94.4	602	387	98.7	376.48	Meteorology: Earth orientation allowed complete global cloud cover pictures each 24 hours. Contained APT for local read-out, AVCS for day and HRIR for night-time cloud cover. Operated about 26 days. (WTR).
OGO-I 1964 54A	Atlas-Agena	5 Sep		3840.1	103,827	45,880	58.8	486.71	Interdisciplinary Studies: Earth-sun interplanetary space interrelationships using a highly elliptical orbit to correlate studies of energetic particles and fields, atmospheric physics, solar and other emissions, interplanetary dust. Not all experimental booms deployed properly thereby interferring with the stabilization systems. Mission unsuccessful.
Saturn I (SA-7) 1964 57A	Saturn I	18 Sep	22 Sep 64	88.4	226,869	183,426	31.7	17,781	Vehicle Development: Seventh straight Saturn I success. Successful demonstration of Launch Escape System jettisonning.
Explorer XXI (IMP-B) 1964 60A	Delta (DSV-3C)	4 Oct	Jan 66	2100	95,338	19,629	33.5	61.23	Particles and Fields: Detailed study of environment of cislunar space through cosmic ray, solar wind, and magnetic field measurements.

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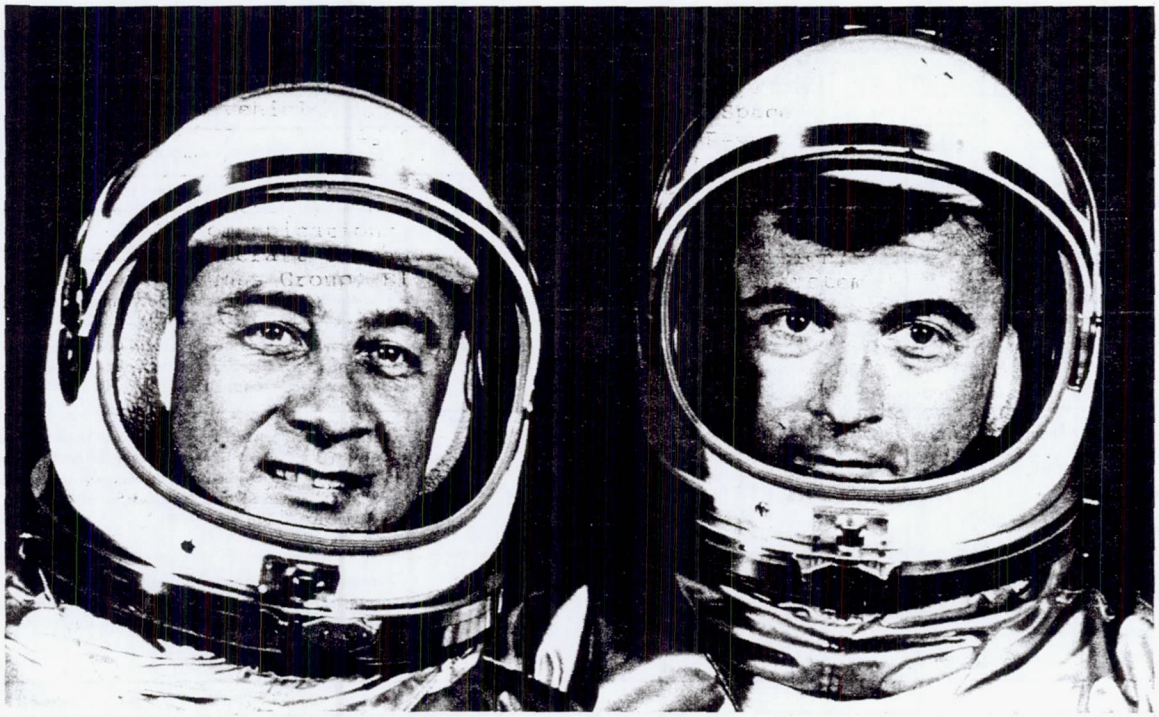
MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
RFD-2	Scout	9 Oct	9 Oct 64	SUBORBITAL FLIGHT				217.6	AEC Reactor Mockup Reentry Flight (Reimbursable).
Explorer XXII 1964 64A	Scout	10 Oct		104.6	1075	887	79.7	52.61	Ionosphere: Measurement of total electron content of ionosphere by effect on four fixed frequencies transmitted to ground. (WTR)
Mariner III 1964 73A	Atlas-Agena	5 Nov		TRANS MARS TRAJECTORY				260	Planetary Exploration; Mars: Shroud failed to jettison and communications with the spacecraft were lost.
Explorer XXIII (S-55c) 1964 74A	Scout	6 Nov		98	879	453	51.9	133.8	Micrometeoroids: Primary sensors were 1- and 2-mil stainless steel pressurized cells; first extended flight test for capacitor detector. Last transmission 29 Nov 64. (WI)
Explorer XXIV (Air Density) 1964 76A	Scout	21 Nov	18 Oct 68	116	2495	553	81.4	9	Atmospheric Physics: First NASA dual payload launch. Air Density is a 12-foot sphere (Explorer IX and XIX design). Comparison of charged particle energy injection (Injun) with variations in atmospheric temperature and density. Last transmission 25 Jul 66. (WTR)
Explorer XXV (Injun) 1964 76B				116	2468	530	81.3	41	
Mariner IV 1964 77A	Atlas-Agena	28 Nov		TRANS MARS TRAJECTORY				260	Planetary and Interplanetary Exploration; Mars: Encounter occurred 14 Jul 65 with closest approach 6118 miles. 22 pictures taken. Mariner IV, V, earth station data obtained Aug-Sep 67.

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NASA Major Launch Record 1964

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Apollo Max. Q Abort Suborb	Little Joe II #5	8 Dec	8 Dec 64					42,593	Apollo LES Development: First test of Apollo emergency detection system at abort attitude; first test of the Canard subsystem (for turn-around and stabilization of spacecraft after launch escape) and of the spacecraft protective cover. (BP #23) (White Sands Missile Range)
Centaur Test IV (AC-4) 1964 82A	Atlas-Centaur	11 Dec	12 Dec 64	87	172	162	30.6	2993	Vehicle Development: Carried mass-model of Surveyor spacecraft. All primary mission objectives met, test successful; however, secondary test of second burn not accomplished.
San Marco I (SM-A) 1964 84A	Scout	15 Dec	13 Sep 65	95	820	205	37.8	113	Atmospheric Physics: Italian payload; Italian launched. (WI) (International Cooperative)
Explorer XXVI (S-3c) 1964 86A	Delta (DSV-3C)	21 Dec		Current Elements Not Maintained				46	Particles and Fields: Study of injection, trapping, and loss mechanisms of the trapped radiation belt, both natural and artificial. Last transmission 21 Jan 67.
1965									1965
Gemini II Suborb	Titan II	19 Jan	19 Jan 65					3122	Space Vehicle Development: Unmanned reentry test at maximum heating rate; demonstrated structural integrity and systems performance of the spacecraft throughout flight, reentry, and parachute water landing.
Tiros IX 1965 4A	Delta (DSV-3C)	22 Jan		119	2581	705	96.3	138	Meteorology: First Tiros "cartwheel" configuration for increased coverage of world cloud cover; elliptical orbit. Turned off 15 Feb 67.

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Astronauts Virgil I. Grissom and John W. Young, Gemini III (launched March 23, 1965).

NASA Major Launch Record

1965

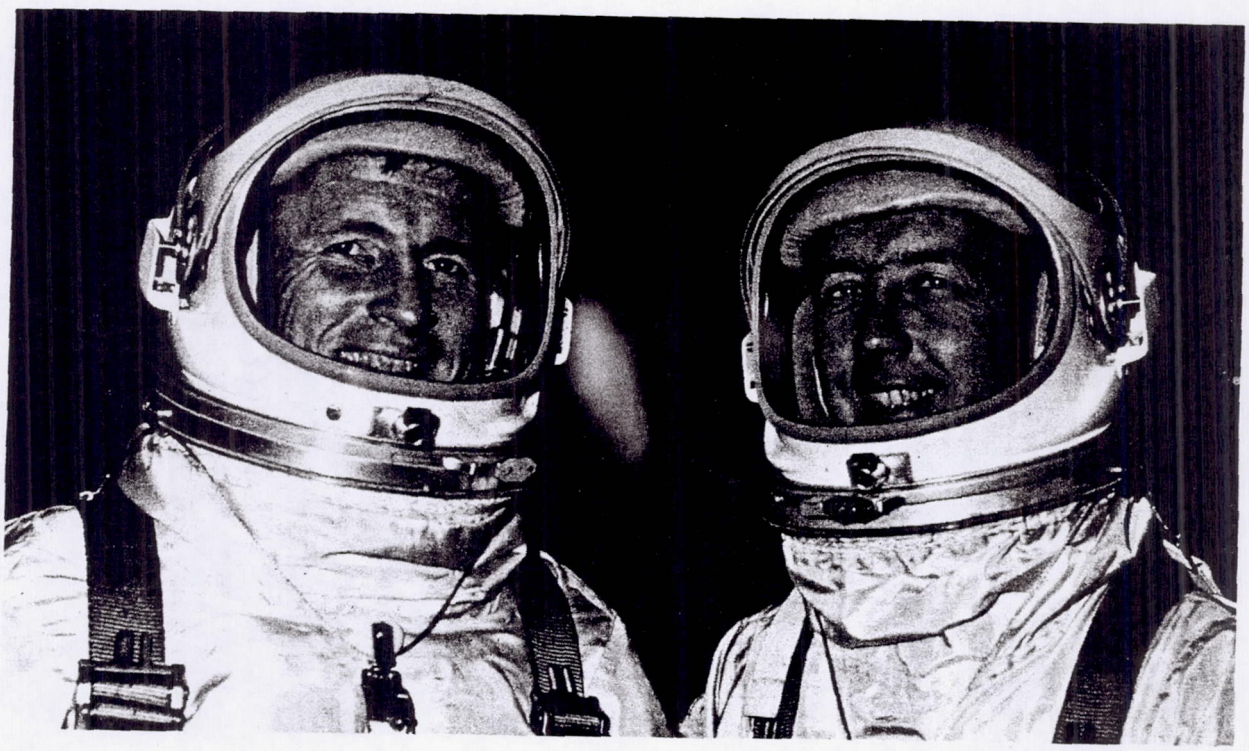
MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
OSO-II 1965 7A	Delta (DSV-3C)	3 Feb		96	600	533	32.8	245	Solar Physics: Continuation of OSO-I studies with added ability to scan the solar disc and part of corona. Last transmission 7 Oct 66.
Pegasus I 1965 9A	Saturn I (SA-9)	16 Feb	17 Sep 78	95	589	457	31.7	1451	Micrometeoroids: First primary use of capacitor-type penetration detector; sensor area: 2000 sq. ft. Data collection terminated 13 Jan 68.
Ranger VIII 1965 10A	Atlas-Agena	17 Feb	20 Feb 65		LUNAR TRAJECTORY			365	Lunar Photography: 7137 pictures obtained; impact occurred about 15 miles from target in Sea of Tranquility. Total flight time to impact: 64 hours 53 minutes.
Centaur Test V (AC-5) Suborb	Atlas-Centaur	2 Mar	2 Mar 65					2540	Vehicle Development: First attempt to place a Surveyor Dynamic Model in a simulated lunar transfer trajectory; Atlas booster failed about 4 seconds after lift-off.
Ranger IX 1965 23A	Atlas-Agena	21 Mar	24 Mar 65		LUNAR TRAJECTORY			366	Lunar Photography: 5814 pictures obtained; impact less than 3 miles from target in eastern floor of crater Alphonsus. Pictures converted for "live" viewing on commercial TV. Final mission of Ranger series. Total flight time to impact: 64 hours 31 minutes.

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Satellite Handbook

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Gemini III 1965 24A	Titan II	23 Mar	23 Mar 65					3225	First Manned Gemini; First US Two-Man Crew: Virgil I. Grissom and John W. Young; 3 orbits, 4 hours 53 minutes. First use by crew of orbital maneuvering system. First control of reentry flight path using variable spacecraft lift.
Intelsat I F-1 (Early Bird I) (HS-303) 1965 28A	TAD (DSV-3D)	6 Apr		1435	35,781	35,739	6.4	39	Communications: First commercial satellite launched by NASA for the Comsat Corp. on a reimbursable basis; up to 240 voice channels, television or high speed data. Geostationary orbit over about 27.5°west longitude.
					GEOSYNCHRONOUS ORBIT				
Explorer XXVII (BE-C) 1965 32A	Scout	29 Apr		108	1316	945	41.1	61	Geodesy: Ultrastable oscillators for precise Doppler tracking of orbital perturbations to obtain description of earth's gravitational field; further laser tracking experimentation. Continuation of Explorer XXII (BE-B) ionospheric measurements. (WI)
Apollo High Alt. Abort Suborb	Little Joe II #6	19 May	19 May 65						Apollo LES Development (BP #22): Launch vehicle developed a high spin during early powered flight and eventually disintegrated. Launch escape system satisfactorily sensed vehicle malfunction and separated the spacecraft without damage. High altitude abort test objectives not met. (White Sands Missile Range)
FIRE II Suborb	Atlas-X259	22 May	22 May 65					86	Reentry test: Second and last flight of FIRE program. Reentry velocity of 37,252 achieved. Excellent data, complementing FIRE I data, obtained.

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(Left to right) astronauts Edward H. White, II, pilot, and James A. McDivitt, command pilot, Gemini IV (launched June 3, 1965).

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Pegasus II 1965 39A	Saturn I (SA-8)	25 May		96	622	476	31.7	1451	Micrometeoroids: Data system improved for increased data reliability. Spacecraft circuitry altered to decrease loss of area due to shorting. Near-earth micrometeoroid environment data was obtained. Data collection terminated 14 Mar 68.
Explorer XXVIII (IMP-C) 1965 42A	Delta (DSV-3C)	29 May	4 Jul 68	8558	263,604	194	33.9	59	Particles and Fields: Continuation of IMP study of solar-terrestrial relationships, especially magnetosphere boundary; cislunar radiation environment. Orbit somewhat higher than planned.
Gemini IV 1965 43A	Titan II	3 Jun	7 Jun 65	89	281	162	32.0	3574	Manned; Long Duration: James A. McDivitt and Edward H. White; 62 orbits, 97 hours 56 minutes. First US extravehicular activities (36 minutes duration) and first use of personal propulsion unit (both by White). A program of eleven scientific experiments was successfully conducted. Near-rendezvous with booster not achieved.
Tiros X (OT-1) 1965 51A	TAD (DSV-3C)	2 Jul		100	835	741	98.6	132	Meteorology: First Weather Bureau funded spacecraft; spin-stablized configuration with two 104° TV cameras, similar to Tiros VI. Placed in near-perfect sun-synchronous orbit.

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(Left to right) astronauts Charles Conrad, Jr., pilot, and L. Gordon Cooper, Jr., command pilot, Gemini V (launched August 21, 1965).

NASA Major Launch Record

1965

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Pegasus III 1965 60A	Saturn I (SA-10)	30 Jul	4 Aug 69	95	567	535	28.9	1452	Micrometeoroids: Last of current Pegasus program. Removable "coupons" added for possible retrieval of thermal coating samples for degradation and cratering study. Last of Saturn I vehicle program with 10 out of 10 successes. Data collection terminated 29 Aug 68.
Scout Evaluation Vehicle (SEV-A) 1965 63A	Scout (S-131-R)	10 Aug		122	2420	1140	69.2	20	Vehicle Development: Evaluated new Castor II (second stage), FW-4S motor (fourth stage); qualified new spacecraft adapter/separation system; demonstrated yaw maneuver ability, air transportability of fully assembled live Scout. Orbited US Army Secor geodetic satellite. Last transmission 10 Sep 65. (WI)
Centaur Test VI (AC-6) 1965 64A	Atlas-Centaur	11 Aug		BARYCENTRIC ORBIT				945	Vehicle Development: Fourth successful Atlas-Centaur launch accurately injected Surveyor dynamic model (SD-2; weight shown at left) into simulated lunar transfer trajectory; demonstrating capability of guidance system.
Gemini V 1965 68A	Titan II	21 Aug	29 Aug 65					3604	Manned: L. Gordon Cooper, Jr. and Charles Conrad, Jr; 120 revolutions. 190 hours 56 minutes (8 days). Demonstrated physiological feasibility of lunar mission; evaluated spacecraft performance. Successful simulated rendezvous and 16 of 17 experiments performed; first Gemini use of fuel cell.

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NASA Major Launch Record

1965

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
OSO-C Suborb	Thor-Delta (DSV-3C)	25 Aug	25 Aug 65					281	Solar Physics: Spacecraft similar to OSO-I and II; failed to orbit: premature ignition of third stage (X-258).
OGO-II 1965 81A	TAT	14 Oct		104	1517	415	87.4	522	Interdisciplinary Studies: Similar to OGO-I but in nearly polar, low altitude orbit, emphasizing atmospheric studies and World Magnetic Survey. All appendages successfully deployed and three-axis stabilization temporarily achieved; operated in spin mode due to Horizon Scanner anomaly. Observatory operations discontinued 22 Feb 68. (WTR)
Gemini VI	Atlas-Agena	25 Oct	25 Oct 65					3252	Rendezvous and Docking Capability Development, Manned Space Flight: Gemini 6 spacecraft was not launched. Agena apparently exploded at initiation of first burn.
Explorer XXIX (GEOS-A) 1965 89A	TAD	6 Nov		120	2273	1117	59.3	174	Geodesy: Intercomparison of satellite tracking system accuracies, investigate earth's gravitational field, improve world-wide geodetic datum accuracies and improve positional accuracies of satellite tracking sites. First improved Delta vehicle. Last transmission 16 Jan 67.
Explorer XXX (SE-A) 1965 93A	Scout	19 Nov		100	899	682	59.7	57	Solar Physics: Monitoring of solar X-rays; to be correlated with optical and radio ground-based observations. NRL satellite, part of IQSY program. Last transmission 7 Nov 67. (WI)

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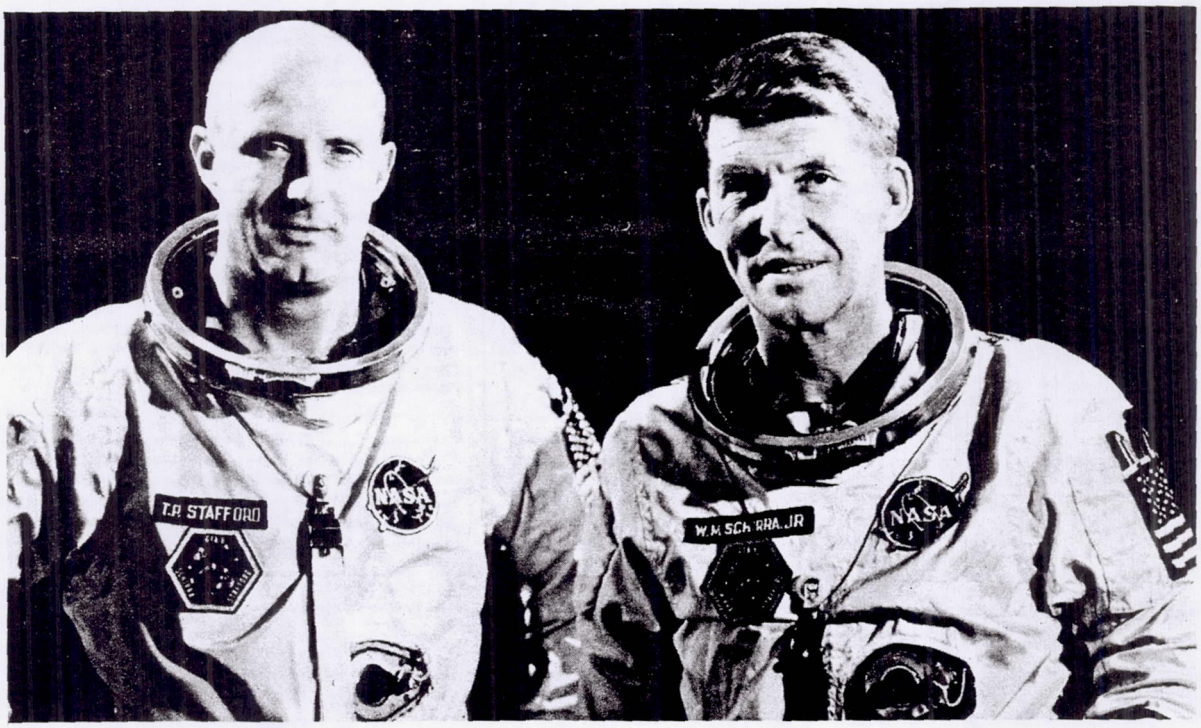
MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
ISIS-X Alouette II 1965 98 A	TAg-B	29 Nov		121	2935	508	79.8	146	Ionosphere: Dual launch for swept frequency topside sounding (Alouette) and direct compositional measurement (DME) of the ionosphere and for comparable data especially during proximity of initial orbits. First of ISIS series, continuation of joint Canadian-US program. (WTR)
Explorer XXXI (DME-A) 1965 98B	TAg-B	29 Nov		121	2963	507	79.8	121	
Gemini VII 1965 100A	Titan II	4 Dec	18 Dec 65					3663	Manned: Frank Borman and James A. Lovell, Jr.; 206 revolutions, 330 hours 35 minutes. Extension of physiological testing and spacecraft performance evaluation. Target for first rendezvous (with Gemini VI-A).
French-1A (FR-1A) 1965 101A	Scout	6 Dec		99	754	742	75.8	61	Ionosphere: Study of VLF wavefield in the magnetosphere and irregularities in distribution of the ionosphere. Spacecraft was designed, constructed, and tested by the Centre National d'Etudes in France. Last transmission 21 Aug 68. (WTR) (International Cooperative)
Gemini VI-A 1965 104A	Titan II	15 Dec	16 Dec 65					3545	Manned: Walter M. Schirra, Jr. and Thomas P. Stafford; 15 revolutions, 25 hours 51 minutes. Accomplished first rendezvous coming within 6 feet of Gemini VII; station keeping was maintained for 5-1/2 hours.
Pioneer VI (Pioneer A) 1965 105A	TAD (DSV-3E)	16 Dec		HELIOCENTRIC ORBIT				64	Particles and Fields: Study of interplanetary phenomena in ciscytherean space to within about 0.814 AU. Five of 6 experiments functioned.

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(left to right) astronauts J. A. Lovell, Jr., and Frank Borman, Gemini VII (launched December 4, 1965).

(Left to right) astronauts Thomas P. Stafford, pilot, and Walter M. Schirra, Jr., Gemini VI-A (launched December 15, 1965).



NASA Major Launch Record

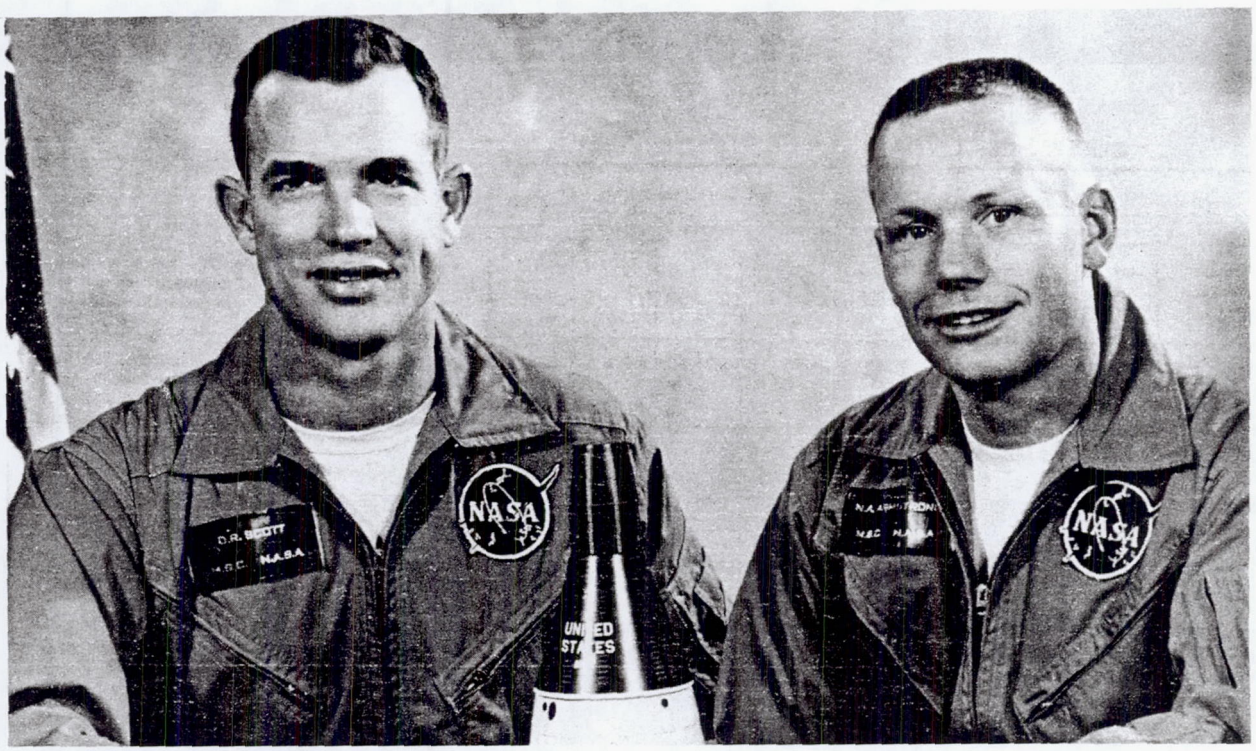
1966

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Intermediate Altitude Abort (LJ II #5) Suborb	Little Joe II L/V #7	20 Jan	20 Jan 66					4989	Apollo LES Development (CSM 002): Last of unmanned ballistic flights; testing Apollo spacecraft atmospheric flight abort capabilities. (White Sands Missile Range)
ESSA I (OT-3) 1966 08A	Delta (DSV-3C)	3 Feb		100	839	701	97.8	138	Meteorology: Initiated the Tiros Operational Satellite (TOS) system, designated Environmental Survey Satellite (ESSA) No. 1. (TV sensor system). Turned off 8 May 67. (Reimbursable)
Reentry V (E) Suborb	Scout	9 Feb	9 Feb 66					95	Reentry Heating Test: Evaluation of the char integrity of a low density phenolic-nylon ablator at 27,000 fps. (WI)
Apollo Saturn Suborb	Satum IB SA-201	26 Feb	26 Feb 66					15,331	Launch Vehicle Development: Unmanned, suborbital; demonstrated the compatibility and structural integrity of the spacecraft/launch vehicle configuration; evaluated heatshield performance at high heating rate; command module (009) recovered.
ESSA II (OT-2) 1966 16A	Delta (DSV-3E)	28 Feb		113	1417	1356	100.9	131	Operational Meteorological Satellite: Advanced version of cartwheel configuration. Permits local readout of daylight cloud cover by Automatic Picture Transmission (APT) TV system. Polar, sun-synchronous orbit. (Reimbursable)

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Gemini VIII 1966 20A 1966 19A	Titan II Atlas-Agena (Target Vehicle)	16 Mar 16 Mar	17 Mar 66 15 Sep 67					3550	Manned: Neil A. Armstrong and David R. Scott; 7 revolutions; 10 hours 42 minutes. First dual launch and docking with Agena. Mission curtailed by short ciurcuit in Orbital Attitude Maneuvering System (OAMS) depleting fuel through thruster #8. First Pacific landing (in preplanned emergency landing area). Target vehicle exercised through 8-day active life; was available for passive rendezvous.
Centaur Test VII (AC-8) 1966 30A	Atlas-Centaur	8 Apr	5 May 66	89	334	175	30.8	785	Vehicle Development: Seventh Atlas-Centaur development flight. Major objective: simulate lunar transfer trajectory using parking orbit, "two burn" indirect ascent. Nominal second burn not achieved. Payload: Surveyor mass model.
OAO-1 1966 31A	Atlas-Agena	8 Apr		100	803	790	35	1769	Astronomy: Capable of accurate long duration pointing for ultraviolet, X-ray and gamma-ray observations and mapping anywhere in celestial sphere. Spacecraft lost after 2 days due to spacecraft systems anomalies.
Nimbus II 1966 40A	TAT-Agena B	15 May		108	1182	1096	100.4	419	Meteorology: R&D similar to earth-oriented Nimbus I with AVCS, APT, and HRIR. Added: Medium Resolution IR Radiometer (MRIR) for earth heat balance HRIR, readout by APT, and orbit data shown on APT. Completed over 2½ years operation with three-axis stabilization. Spacecraft ceased to operate as of 17 Jan 69. (WTR)

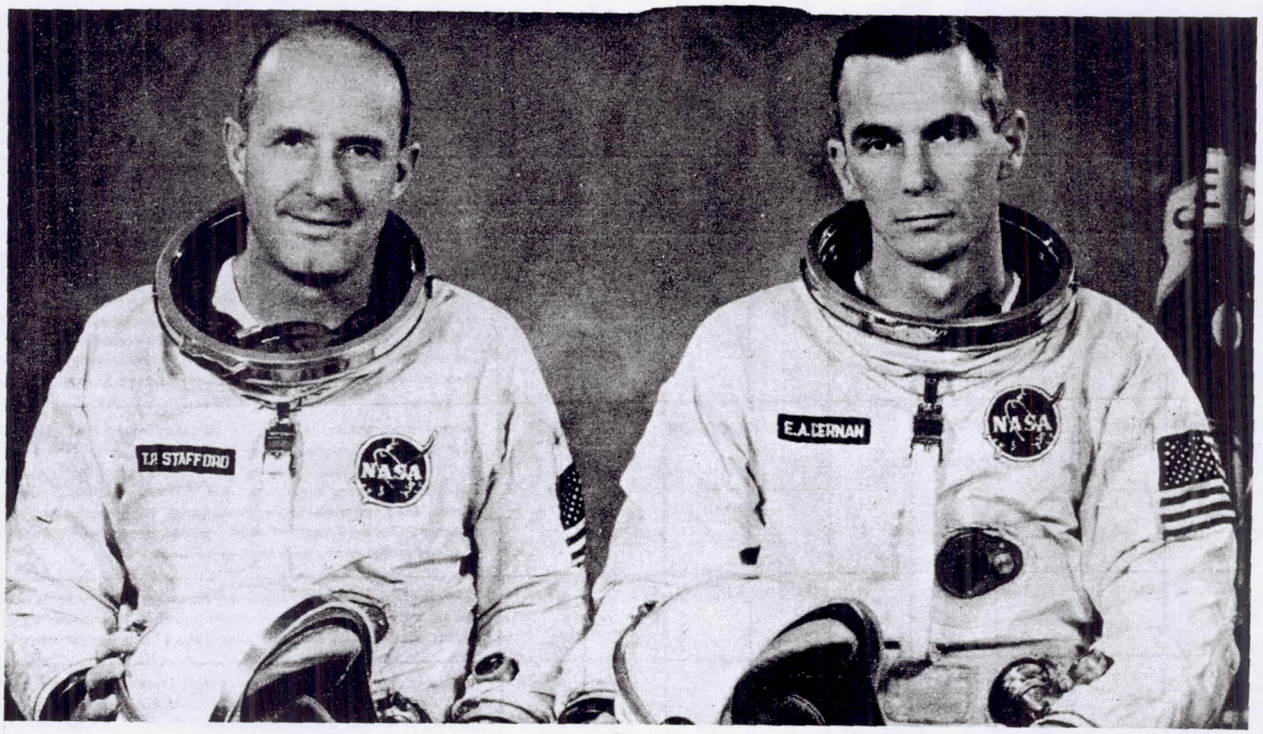
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(Left to right) astronauts David R. Scott and Neil A. Armstrong, command pilot, Gemini VIII (launched March 16, 1966).

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Gemini IX Suborb	Atlas-Agena	17 May	17 May 66					3252	Manned Flight Development: Rendezvous and docking development and to evaluate docked vehicle maneuvering capability and EVA. Target vehicle failed to orbit due to Atlas malfunction; Gemini 9 spacecraft not launched.
Explorer XXXII (AE-B) 1966 44A	Delta (DSV-3C-1A)	25 May		110	2257	257	64.6	222	Aeronomy: Similar to Explorer XVII but with solar cells for extended life. Apogee higher than planned 650 NM but sensors operated to low levels revealing He and H ion distribution in lower exosphere. Last transmission 31 Mar 67.
Surveyor I 1966 45A	Atlas-Centaur AC-10	30 May	2 Jun 66		LUNAR TRAJECTORY			995	Lunar Exploration: Achieved soft lunar landing on first engineering test flight (with closed loop guidance) at 02:17 EDT at 2.41°S, 43.43°W (Ocean of Storms). Selenological data obtained on morphology and lunar origin; bearing strength at Surveyor I site and footpad scale about 5 psi; surface material small cohesive particles with rocks up to 3 feet in size; no loose dust. 10,338 pictures taken during first lunar day, 899 during second (total: 11,237) last contact 7 Jan 67.
Gemini IX-A 1966 47A 1966 46A	Titan II Atlas (Target Vehicle)	3 Jun 1 Jun	6 Jun 66 11 Jun 66					3550	Manned: Thomas P. Stafford and Eugene A. Cernan; 44 revolutions; 72 hours, 21 minutes. Unable to dock with ATDA (backup for Gemini Target Vehicle) when shroud failed to clear docking adapter. 2 hours 7 minutes of EVA accomplished; use of Astronaut Maneuvering Unit prevented by difficulty of donning unit and fogging of spacesuit faceplate.

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(Left to right) astronauts Thomas P. Stafford, command pilot, and Eugene A. Cernan, pilot, Gemini TX-A (launched June 3, 1966).

NASA Major Launch Record

1966

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
OGO-III 1966 49A	Atlas-Agena B	7 Jun		2910	103,129	19,173	77.7	514	Interdisciplinary Studies: First fully successful OGO; first three-axis stabilization in highly elliptical earth orbit (viewing earth, space, sun, and orbital plane). Planned apogee reduced to assure earth tracking throughout orbit. Essentially same experiment complement as OGO-I.
Pageos I 1966 56A	TAT	24 Jun		180	4903	3496	86.4	111	Geodesy: Established world-wide triangulation network by optical sighting of ECHO I type sphere. (100-foot diameter) (WTR)
Explorer XXXIII (IMP-D) 1966 58A	TAD	1 Jul		Current Elements Not Maintained				94	Particles and Fields: Planned anchored lunar orbit not obtained. Excess energy orbit produced by launch vehicle precluded lunar capture; consequently, spacecraft was placed in highly elliptical orbit about the earth.
Apollo Saturn 1966 59A	Saturn IB SA-203	5 Jul	5 Jul 66	88	212	183	31.98	26,535	Launch Vehicle Development: Liquid hydrogen evaluation flight of the S-IVB stage vent and restart capability. Also test of S-IVB/IU separation and cryogenic storage at zero "G". Flight terminated during liquid hydrogen pressure and structural test.

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NASA Major Launch Record

1966

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Gemini X 1966 66A 1966 65A	Titan II Atlas-Agena (Target Vehicle)	18 Jul 18 Jul	21 Jul 66 29 Dec 66					3550	Manned: John W. Young and Michael Collins; 43 revolutions; 70 hours 47 minutes. First dual rendezvous (with GTV 10 then with GTV 8); first docked vehicle maneuvers; three hatch openings: stand-up EVA - 87 minutes, terminated due to fumes; umbilical EVA - 27 minutes, terminated to conserve maneuvering propellant on spacecraft; equipment jettisoned before reentry. Micrometeoroid experiment retrieved from GTV 8.
Lunar Orbiter I 1966 73A	Atlas-Agena	10 Aug	29 Oct 66	LUNAR TRAJECTORY				383	Lunar Photography: Total of 207 sets (frames) of medium and a high resolution pictures taken; 38 from initial, 169 from low orbit. Areas covered: 9 primary and 7 potential Apollo landing sites (including Surveyor I site), 11 backside and 2 earth-moon. Medium resolution pictures good, high resolution smeared. Readout completed 13 Sep 66, intentionally impacted to avoid interference with second mission.
Pioneer VII 1966 75A	Delta	17 Aug		HELIOCENTRIC ORBIT				64	Particles and Fields: Continued program of measurements over the solar cycle at widely separated points in interplanetary space; about 1.125 AU aphelion. Four of 6 experiments on.
Apollo Saturn Suborb	Saturn IB AS-202	25 Aug	25 Aug 66					20,275	Apollo Launch Vehicle and Spacecraft Development: Unmanned, suborbital. Continued test of CSM subsystems and space vehicle structural integrity and compatibility. 1 hour 23 minute flight evaluated heat-shield performance at high heat load; CM 011 recovered near Wake Island.

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Gemini XI 1966 81A 1966 80A	Titan II Atlas-Agena (Target Vehicle)	12 Sep 12 Sep	15 Sep 66 30 Dec 66					3550	Manned: Charles Conrad, Jr. and Richard F. Gordon, Jr; 44 revolutions; 71 hours 17 minutes. Rendezvous and docking achieved in 1 hour 34 minutes within first spacecraft revolution. 2 hours 41 minutes EVA by Gordon; umbilical EVA 44 minutes. Tethered spacecraft experiment successful, computer controlled reentry.
Surveyor II (AC-7) 1966 84A	Atlas-Centaur	20 Sep	23 Sep 66		LUNAR TRAJECTORY			1000	Lunar Exploration: During midcourse maneuver, one of the three spacecraft's vernier engines did not ignite causing incorrectable tumbling. Contact lost 5½ hours prior to predicted impact time. Target Site: Sinus Medii.
ESSA III (TOS-A) 1966 87A	Delta (DSV-3E)	2 Oct		114	1488	1388	100.9	147	Meteorology: First Advanced Vidicon Camera System (AVCS) in Tiros/TOS series; also carried IR earth heat balance sensor. Advanced cartwheel design; placed in near polar sun-synchronous orbit. First Delta vehicle launch from Western Test Range. (Reimbursable)
Centaur Test VIII (AC-9) 1966 95A	Atlas-Centaur	26 Oct	6 Nov 66					738	Vehicle Development: Second "two-burn" test for parking orbit, indirect ascent capability; eighth and final Centaur development test planned. Surveyor mass model injected into simulated lunar transfer orbit.

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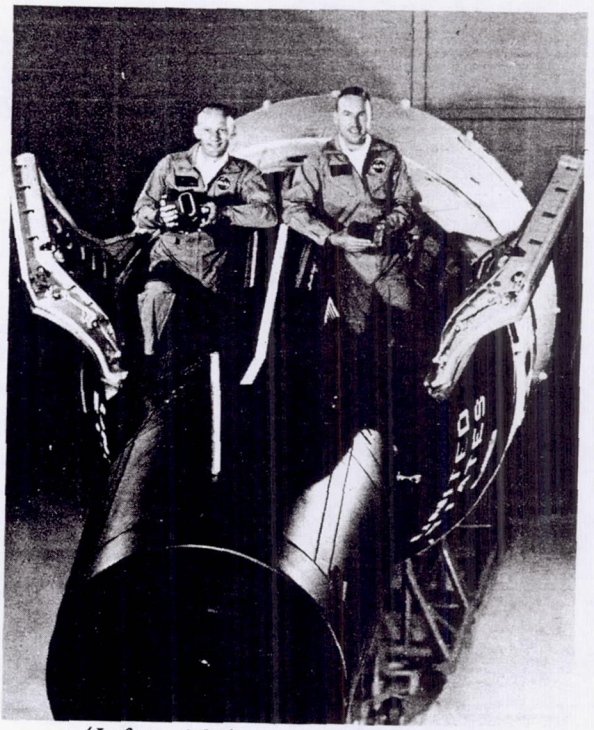
Astronauts John W. Young and Michael Collins, Gemini X (launched July 18, 1966).

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Intelsat II F-1 (HS-303A) 1966 96A	Delta (DSV-3E)	26 Oct		718	37,154	3220	16.8	87	Communications: Second Comsat Corp. commercial satellite, NASA providing reimbursable launch support. Apogee motor nozzle blown off shortly after motor ignited. Planned geo-stationary orbit not achieved. Spacecraft orbit allowed about 8 hours of use per day. Last transmission 31 Oct 66.
Lunar Orbiter II 1966 100A	Atlas-Agena	6 Nov	11 Oct 67		LUNAR TRAJECTORY			385	Lunar Photography: Spacecraft completed taking 211 frames (422 medium and high resolution pictures) on 26 Nov 66. Spacecraft responded to over 2870 commands and performed over 280 maneuvers. Readout was completed 6 Dec 66.
Gemini XII 1966 104A 1966 103A	Titan II Atlas-Agena (Target Vehicle)	11 Nov 11 Nov	15 Nov 66 23 Dec 66					3550	Manned: James A. Lovell, Jr. and Edwin E. Aldrin, Jr; 59 revolutions; 94 hours 34 minutes. Final mission of Gemini series emphasized evaluation of EVA (Aldrin: 5 hours 30 min.) tasks workload including two "standups" totaling 208 minutes and 122 minutes of umbilical EVA. Also 14 scientific experiments performed and solar eclipse pictures taken. The target vehicle's primary propulsion not usable for high elliptical orbit maneuver.
ATS-I 1966 110A	Atlas-Agena	7 Dec		1436	35,824	35,750	4.0	352	Applications and Technology: Synchronous, circular equatorial orbit over 151°W longitude (near Hawaii). The Spin Scan Cloud Camera returned the first photo covering nearly the entire disc of the earth on 9 Dec 66. Communications, spacecraft technology, and science experiments included in payload.
					GEOSYNCHRONOUS ORBIT				

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(Left to right) astronauts Richard F. Gordon, Jr., pilot, and Charles Conrad, Jr., Gemini XI (launched September 12, 1966).



(Left to right) astronauts Edwin E. Aldrin, Jr., pilot, and James A. Lovell, Jr., command pilot, Gemini XII (launched November 11, 1966).

NASA Major Launch Record

1966

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Biosatellite I 1966 114A	Delta (DSV-3G)	14 Dec	15 Feb 67	91	89	86	33.5	431	Biology: Spacecraft completed 3 days of operation with good environmental control and attitude control. All biological experiment events occurred. The radiation source functioned as planned. Retrofire did not occur and recovery was not possible.
1967									1967
Intelsat II F-2 (HS-303A) 1967 01A	Delta (DSV-3E)	11 Jan		1435	35,789	35,753	2.3	87	Communications: Comsat commercial satellite; NASA providing reimbursable launch support. Capable of handling TV data transmission or up to 240 voice channels; part of capacity to be purchased by NASA for Apollo support. Placed about 164°East in the vicinity of the Marshall Islands. Last transmission 14 Jan 67. (Reimbursable)
				GEOSYNCHRONOUS ORBIT					
ESSA IV (TOS-B) 1967 06A	Delta (DSV-3E)	26 Jan		113	1442	1327	102.0	132	Meteorology: Advanced version of cartwheel configuration. Nearly-polar sun-synchronous orbit. Good APT pictures returned on 28 Jan 67. 29 Jan 67 shutter problem made one (of two redundant) APT cameras aboard inoperative. (WTR) Deactivated 6 Dec 67. (Reimbursable)
Lunar Orbiter III 1967 08A	Atlas- Agena	5 Feb	9 Oct 67	LUNAR TRAJECTORY				385	Lunar Photography: 211 sets (frames) of medium and high resolution pictures taken. Last frame not taken to cut bimat early. Picture readout terminated by a transient signal which ended film movement. 72% of photos readout. Readout completed for six primary sites, parts of six other sites. Partial readout returned on 31 secondary sites.

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Launch Record

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
OSO-III (OSO-E) 1967 20A	Delta (DSV-3C)	8 Mar		95	533	510	32.8	284	Solar Physics: Similar to OSO-I and OSO-II; carried experiments identical to OSO-C unsuccessfully launched 25 Aug 65 for obtaining high resolution spectral data within range of 8Å - 1300Å.
Intelsat II F-3 (HS-303A) 1967 26A	Delta	23 Mar		1436	35,816	35,773	3.2	87	Communications: Comsat commercial satellite similar to Intelsat II-A and II-B. Spacecraft placed about 10° West over Atlantic Ocean. (Reimbursable)
				GEOSYNCHRONOUS ORBIT					
ATS-II 1967 31A	Atlas-Agena	6 Apr	2 Sep 69	218	11,177	185	28.4	324	Gravity Gradient Experiment: Lack of Agena second burn resulted in elliptical, not circular, orbit precluding meaningful evaluation of gravity gradient experiment, and resulted in limited data from 11 other experiments; communications, meteorology, albedo, 8 environmental. Unsuccessful.
Surveyor III (C) 1967 35A	Atlas-Centaur	17 Apr	20 Apr 67	LUNAR TRAJECTORY				997	Lunar Exploration: Achieved soft landing on 20 Apr 67. Closed loop radar failed during landing and spacecraft landed three times on inertial guidance before its verniers cut off. Surface Sampler experiment discovered pebbles at 6 inches and 10 psi bearing strength. The spacecraft returned 6315 pictures. Site: Oceanus Procellarum, 3.33°S, 23.17°W.
ESSA V (TOS-C) 1967 36A	Delta (DSV-3E)	20 Apr		113	1423	1357	101.8	147	Meteorology: Carried Advanced Vidicon Camera System. In sun-synchronous orbit with 3:00 p.m. local equator crossing time. Officially deactivated by ESSA 20 Feb 70. (WTR) (Reimbursable)
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NASA Major Launch Record 1967

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
San Marco II 1967 38A	Scout	26 Apr	14 Oct 67	95	801	217	2.9	129	Atmospheric Physics: Italian payload launched from the Platform in the Indian Ocean. Spacecraft carried drag and ionospheric experiments. (International Cooperative)
Lunar Orbiter IV (Lunar Orbiter D) 1967 41A	Atlas-Agena	4 May	6 Oct 67	LUNAR TRAJECTORY				385	Lunar Photography: First photos returned 11 May 67. Problems developed with Camera Thermal Door. Readout completed 27 May 67. High resolution photos of over 99% of frontside of moon returned. Eighty percent of backside has been photographed by Lunar Orbiter I-IV.
Ariel III (UK-E) 1967 42A	Scout	5 May	14 Dec 70	94	505	443	80.1	90	Atmospheric Physics: United Kingdom payload. All five experiments returned data. (International Cooperative) (WTR)
Explorer XXXIV (IMP-F) 1967 51A	Delta	24 May	3 May 69	6215	207,581	3618	71.3	74	Particles and Fields: Fifth IMP spacecraft. Investigating region between the magnetosheath and the shock front. Launched during Class III Bright solar flare. (WTR)
ESRO II-A Suborb	Scout	29 May	29 May 67					69	Solar Astronomy and Cosmic Rays: All telemetry lost eight seconds prior to third-stage cutoff. No fourth-stage burn, satellite landed in South Pacific. (WTR) (International Cooperative)
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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	
Mariner V (Venus 67) 1967 60A	Atlas-Agena	14 Jun		HELIOCENTRIC ORBIT				245	Planetary/Interplanetary Exploration: All science and engineering subsystems nominal through encounter with Venus; data indicates moon-like effect on solar plasma, strong H_2 corona comparable to earth's, 72 to 87% CO_2 atmosphere with balance probably nitrogen, no O_2. Closest approach: 3946 km.
Surveyor IV 1967 68A	Atlas-Centaur (single burn)	14 Jul	17 Jul 67	LUNAR TRAJECTORY				1037	Lunar Exploration: All launch vehicle and spacecraft performance nominal until last 2 seconds of 42 second retro burn when all communications were lost with spacecraft. Target site: Sinus Medii.
Explorer XXXV (IMP-E) 1967 70A	Delta (DSV-3E)	19 Jul		SELENOCENTRIC ORBIT				104	Particles and Fields: Lunar orbit achieved 22 July 67 (first without mid-course correction capability) permitting more detailed study of earth's magnetosphere. No lunar magnetic field or "bow shock wave" observed.
OGO-IV (OGO-D, POGO) 1967 73A	TAT-Agena	28 Jul	16 Aug 72	96.1	751	399	85.9	562	Interdisciplinary Studies: Similar to OGO-II, to obtain data during increased solar activity to complement near solar minimum OGO-II data. Carried 20 experiments (10 from 9 universities, one foreign; 5-GSFC; 1-JPL; 1-SAO; 2-NRL; 1-CRL) emphasizing atmospheric/ionospheric phenomena of near-earth environment. (WTR)

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NASA Major Launch Record 1967

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	
Lunar Orbiter V 1967 75A	Atlas-Agena	1 Aug	31 Jan 68	LUNAR TRAJECTORY				385	Lunar Photography: Last launch in the series of missions to perform mapping of entire lunar surface. Specifically provided: detailed coverage of 36 scientific interest sites; 5 Apollo sites; completed high altitude far side coverage; a full view of earth in near full phase. One hundred percent readout accomplished of all 212 frames taken; provided near-lunar micrometeoroid and radiation data.
Biosatellite II 1967 83A	Delta (DSV-3G)	7 Sep	9 Sep 67	90.8	326	302	33.5	430	Biology: First successful US satellite exclusively for bioscience; obtained excellent data on specimens of cells, plants, and low order animals; reentered one day early. Capsule recovered by aircatch
Surveyor V 1967 84A	Atlas-Centaur	8 Sep	11 Sep 67	LUNAR TRAJECTORY				1006	Lunar Exploration: First alpha scatter data; indicated basaltic character of area sampled in Mare Tranquillitatus, 23.19°E and 1.52°N. Achieved 83 hours alpha scatter data and 18,006 photos in first lunar day. Survived first lunar night but, as expected, subsequent data obtained of lower quality.
Intelsat II F-4 (HS-303A) 1967 94A	Delta (DSV-3E)	28 Sep		1435.8	35,816	35,744	0.4	87	Communications: Comsat commercial satellite, similar to Intelsats II-A, B, and C with up to 240 voice channels; to supplement and backup B. Current orbit 63°W over Pacific Ocean. Provides test of minimum angular separation of B and D without inter-satellite interference. (Reimbursable)

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
OSO-IV (D) 1967 100A	Delta (DSV-3C)	18 Oct		95.5	557	525	32.9	274	Solar Physics: Continuation and expansion of data obtained by OSO program on high resolution spectral data (within range of 1Å - 1350Å) from pointed solar experiments including raster scans of solar disk. Retired 1 Nov 71.
RAM C-1 (RAM C-A) Suborb	Scout	19 Oct	19 Oct 67	Shaped Reentry Trajectory				116	Reentry Environment: Investigation of plasma flow field for solution of associated communications problems of reentry between 25-27,000 fps using water addition techniques. Use of X-band telemetry and plasma and ablation effects on antennas also evaluated. About 25K fps reentry achieved. (WI)
ATS-III (C) 1967 111A	Atlas- Agena	5 Nov		1435	35,781	35,778	0.1	362	Applications and Technology: Nine experiments involving communications, meteorology, earth photography in color, navigation, stabilization and pointing, degradation of surfaces in space and ionosphere.
				GEOSYNCHRONOUS ORBIT					
Surveyor VI (F) 1967 112A	Atlas- Centaur	7 Nov	10 Nov 67	LUNAR TRAJECTORY				1008	Lunar Exploration: Sinus Medii, 0°25'N, 1°3'W. 30,065 TV pictures, 27 hours on-surface alpha scatter analytical time obtained. First liftoff from lunar surface: moved 10 feet to a new location. Sixth in a series of seven Surveyor flights intended to perfect the technology of soft landing on the moon and provide basic scientific and engineering data in support of Apollo.

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NASA Major Launch Record 1967

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Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Apollo IV (AS-501/CSM- 017/LTA-10R) 1967 113A	Saturn V	9 Nov	9 Nov 67	88.3	191	183	32.6	42,506	Launch Vehicle and Spacecraft Development: First launch of Saturn V vehicle (8-1/2 hour mission) to demonstrate launch vehicle capability and spacecraft development. CSM-017 tested Apollo heat shield and simulation of new hatch at lunar reentry velocity; recovered near Hawaii. First launch from Complex 39. Two orbits at 88.3 minutes, then boosted to 1722 km apogee.
ESSA VI (TOS-D) 1967 114A	Delta (DSV-3E)	10 Nov		114.8	1487	1410	102.0	129	Meteorology: Carried two TV systems used for the Automatic Picture Transmission (APT) ground stations. Sun-synchronous orbit. Spacecraft and launch costs funded by ESSA. (WTR) (Reimbursable)
Pioneer VIII (C) (Test & Training Satellite-I) 1967 123A/B	Delta (DSV-3E)	13 Dec 13 Dec	28 Apr 68	HELIOCENTRIC ORBIT				66 18	Particles and Fields: Continued program of measurements over solar cycle at widely separated points in interplanetary space about 1.09 Astronomical Unit Aphelion. Six of 6 experiments functioned. (TTS-1--a "piggyback" secondary objective payload for the checkout, training, and development of MSFN stations and techniques.
1968									1968
Surveyor VII (G) 1968 01A	Atlas- Centaur	7 Jan	10 Jan 68	LUNAR TRAJECTORY				1040	Lunar Exploration: Last Surveyor, emphasized scientific objectives, landed on Tycho ejecta blanket, 40.89°S, 11.44°W; first combination of the three major experiments: TV (2,274 on first day), alpha scatter (43 hours on surface analytical time), and surface sampler.

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NASA Major Launch Record

1968

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Explorer XXXVI GEOS II (B) 1968 02A	Delta (DSV-3E)	11 Jan		112	1570	1079	105.8	212	Geodesy: Nearly identical to GEOS-A with C-band transponder and reflector and CW laser detector added. Continued support of the National Geodetic Satellite Program objectives. (WTR)
Apollo V (AS-204/LM-1) 1968 07A (ascent) 1968 07B (descent)	Saturn IB	22 Jan 22 Jan	24 Jan 68 12 Feb 68	89.5	222	162	31.6	42,506	Lunar Module (LM) Spacecraft Development: First flight test of Apollo LM verified ascent and descent stages propulsion systems, including restart and throttle operations. Also evaluated LM staging and S-IVB/IU orbital performance.
OGO-V (E) 1968 14A	Atlas-Agena D (SLV-3A)	4 Mar		Current Elements Not Maintained				611	Interdisciplinary Studies: Three-axis stabilized in highly elliptical earth orbit. Countries providing experiments include England, France, and the Netherlands. First satellite spark-chamber experiment. First detection of electric fields in earth's bow shock. Retired 14 Jul 72.
Explorer XXXVII (Solar Exp.-B) 1968 17A	Scout	5 Mar		98	870	498	59.4	88	Second joint Naval Research Laboratory-NASA Spacecraft: Monitored sun's energetic X-ray emissions intensity and time histories and provided real-time solar data through COSPAR to scientific community. Six of 8 experiments functioned. Last transmission 16 Mar 70. (WI)

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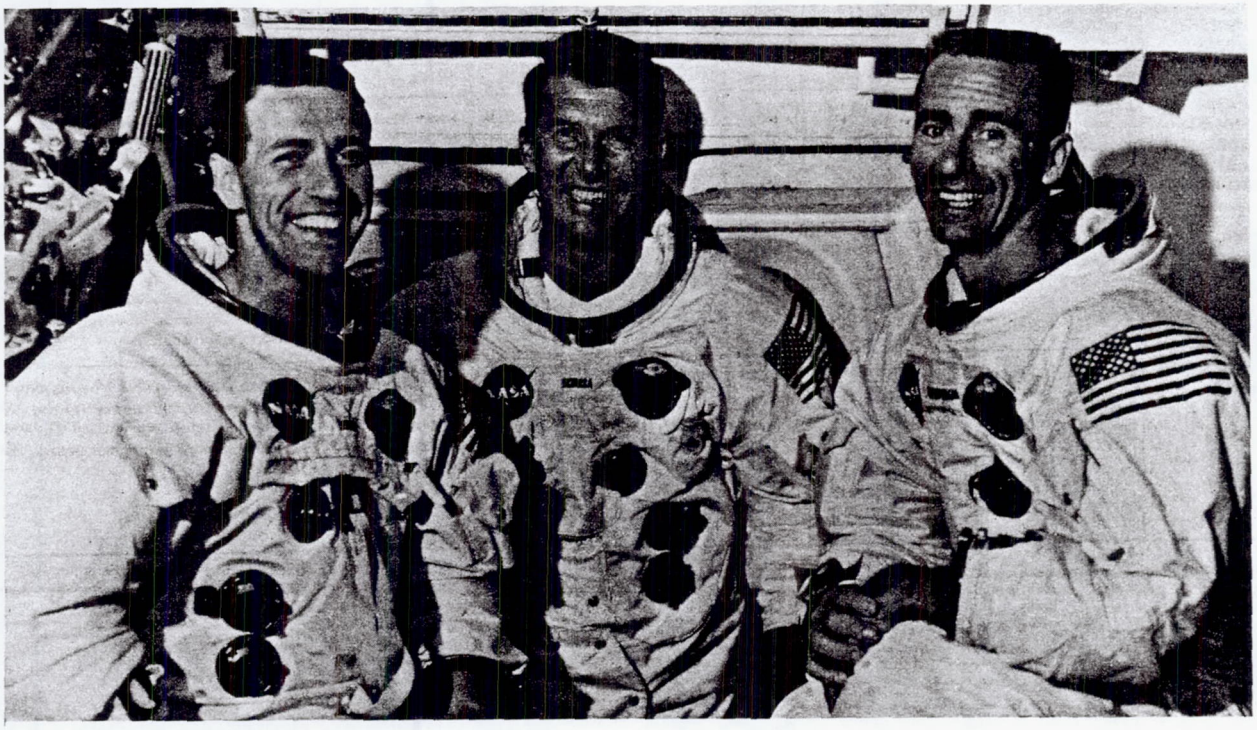
NASA Major Launch Record

1968

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Apollo VI (AS-502/ CSM-020/ LTA-2R) 1968 25A	Saturn V	4 Apr	4 Apr 68					42,856	Launch Vehicle Development Mission: Anomalies experienced with J-2 engine Augmented Spark Ignitors on second and third stages. S-IVB restart not accomplished. F-1 engines on first stage synchronized creating longitudinal vibration of unacceptable amount. Spacecraft performance nominal.
Reentry VI (F) Suborb	Scout	27 Apr	27 Apr 68					272	Reentry Heating Test: Designed to support the advancement of atmospheric entry technology. Spacecraft performance nominal. (WI)
International Radiation Investigation Sat.-I (ESRO-IIB) 1968 41A	Scout	17 May	8 May 71	96.5	869	321	97.2	89	Radiation: The scientific objective resulted in measuring radiation from the sun and cosmic rays, including X-rays, HE, II line, Lyman Alpha, trapped radiation, solar and Van Allen belt protons, cosmic ray protons, Alpha particles, and high energy electrons. (WTR) (International Cooperative)
Nimbus B	Thorad-Agena D	18 May	18 May 68					617	Meteorology: Carried two experiments flown on Nimbus II and five new ones plus RTG (SNAP-19) experiment. Planned 1,111 km sun-synchronous polar orbit. Launch vehicle destroyed by range safety after 2 minutes. (WTR)
Explorer XXXVIII (RAE-A) 1968 55A	Delta	4 Jul		224.3	5856	5845	120.8	275	Radio Astronomy: On 8 Oct 68 the four antennas were deployed to their full and final length of 750 feet (1500 feet tip-to-tip). The damper boom was also extended to its full length of 315 feet (630 feet tip-to-tip). Two of 2 experiments functioned. (WTR)

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(Left to right) astronauts Donn F. Eisele, command module pilot, Walter M. Schirra, Jr., commander, and Walter Cunningham, lunar module pilot, Apollo VII (launched October 11, 1968).



NASA Major Launch Record

1968

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Apollo VII (AS-205/ CSM-101) 1968 89A	Satum IB	11 Oct	22 Oct 68					51,655	Manned, CSM Operations: Walter M. Schirra, Donn F. Eisele, and Walter Cunningham. 10.8 days duration. Eight successful Service Propulsion firings. Seven live TV sessions with crew returned. Rendezvous with S-IVB stage to 70 feet performed. Astronauts developed colds in orbit.
Pioneer IX (D) 1968 100A (Test and Training Satellite) 1968 100B	Delta (DSV-3E)	8 Nov		97.3	895	369	32.8	665 18	To collect scientific data on the electromagnetic and plasma properties of the interplanetary medium for a period covering six or more passages of solar activity centers. Six of 6 experiments functioned (TETRS-2, a "piggyback" secondary objective payload for the checkout, training, and development of MSFN stations and techniques.)
HEOS-A 1968 109A	Delta	5 Dec	28 Oct 75	6699.7	222,263	421	28.2	109	First NASA/ESRO reimbursable mission. Scientific satellite for the investigation of interplanetary magnetic fields and the study of solar and cosmic ray particles. Eight of 8 experiments operated. (Reimbursable)
OAO-II (A2) 1968 110A	Atlas-Centaur	7 Dec		100.2	776	766	34.9	2012	Astronomy: Heaviest, most complex US scientific spacecraft built to date. Astronomy investigations by experiments developed by Univ. of Wisconsin and the Smithsonian Astrophysical Obs. Observational objectives include celestial objects in the ultraviolet region of the electromagnetic spectrum. Three of the four Smithsonian instruments functioned, but this instrument was placed on standby in April 1970 to concentrate on the Wis. instrument. Six of the 7 Wis. instruments functioned.
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Satellite Handbook

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Explorer XXXIX (Air Density) 1968 66A	Scout	8 Aug		117	2340	762	80.7	79	Interdisciplinary project to continue the detailed scientific study of density and radiation characteristics of earth's upper atmosphere at a time of high solar activity. Four of 4 experiments functioned. (WTR)
Explorer XL (Injun V) 1968 66B		8 Aug		118.3	2529	682	80.6	83	
ATS-IV (D) 1968 68A	Atlas-Centaur	10 Aug	17 Oct 68	94	772	217	29.0	390	Applications and Technology: Performed communication, meteorological, technology, and science experiments. Gravity gradient experiment could not be conducted because spacecraft did not separate from Centaur.
ESSA-VII (TOS-E) 1968 69A	Delta	16 Aug		114.9	1476	1432	101.7	147	Meteorology: TOS-E, an AVCS-type spacecraft, in a sun-synchronous orbit having a local equator crossing time between 2:35 p.m. and 2:55 p.m., so that daily AVCS pictures of the entire globe can be obtained. One AVCS operated. (WTR) (Reimbursable)
RAM C-II (C-B) Suborb	Scout	22 Aug	22 Aug 68					122	To measure electron and ion concentrations in the flow field at discrete spacecraft locations during reentry. (WI)
Intelsat III F-1	Delta	19 Sep	19 Sep 68	ORBIT NOT ACHIEVED				282	Communications: Third generation Comsat commercial satellite. Improved long-tank Thor Delta destroyed itself 1 minute, 8 seconds into the mission. Control system failure. (Reimbursable)
Aurorae (ESRO-I) 1968 84A	Scout	3 Oct	26 Jun 70	102.4	1492	262	93.8	85	Carried eight experiments designed to perform an integrated study of the high latitude ionosphere. (WTR) (International Cooperative)

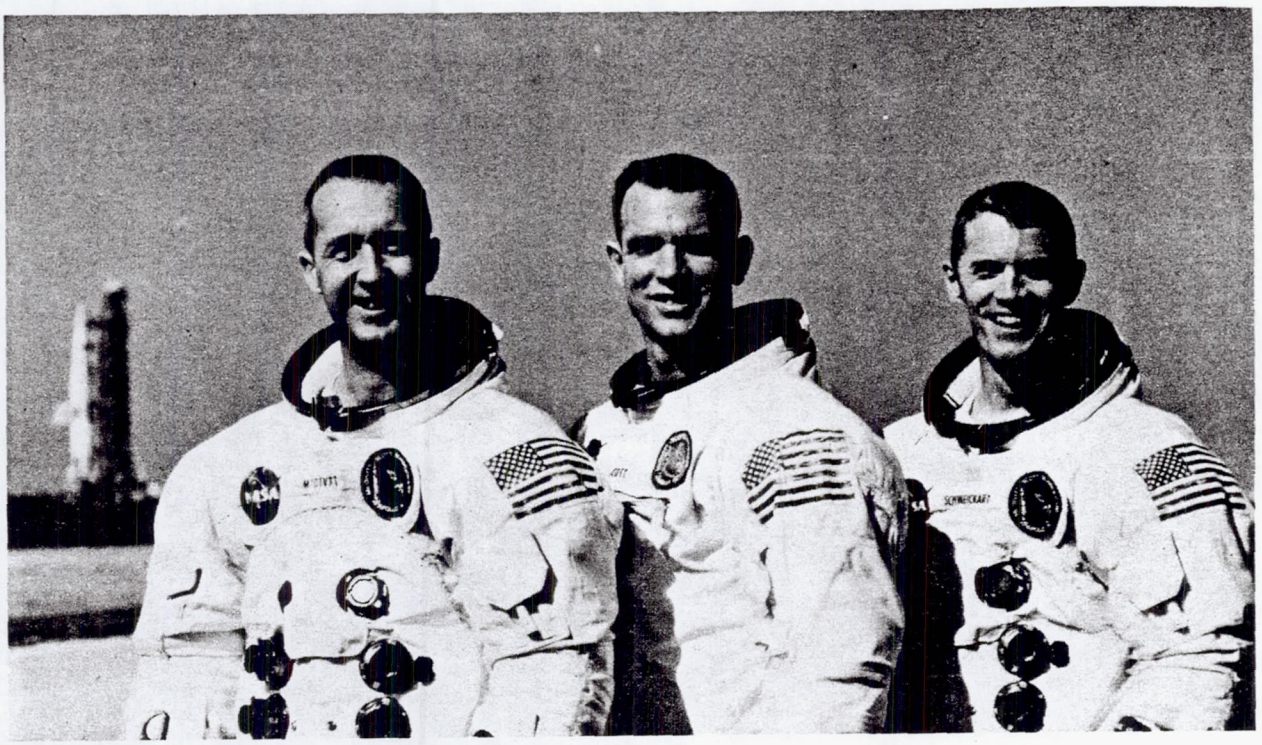
1 lb = 0.4536 kg 1 mi = 1.609 km 1 NM = 1.8515 km

(Left to right) astronauts James A. Lovell, Jr., command module pilot, William A. Anders, module pilot, and Frank Borman, commander, Apollo VIII (launched December 21, 1968).

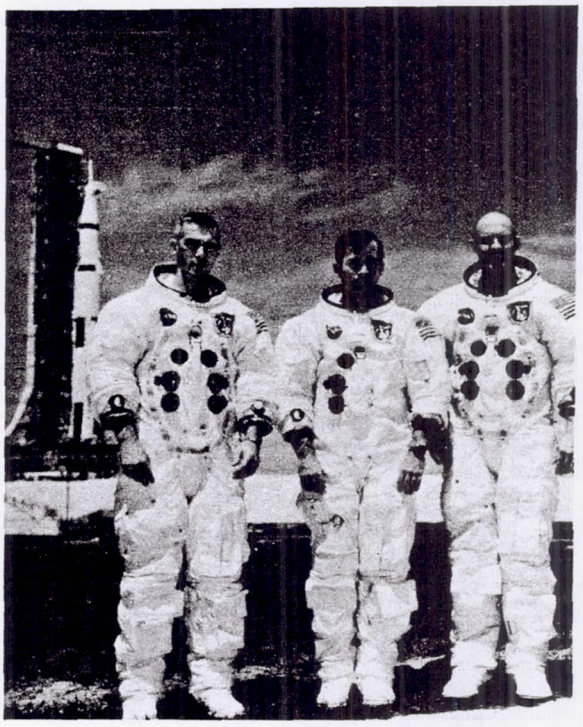


MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
ESSA-VIII (TOS-F) 1968 114A	Delta	15 Dec		114.6	1467	1414	101.8	136	Meteorology: Carries two Automatic Picture Transmission (APT) Camera Systems to obtain daily cloud photos all over the globe. (WTR) (Reimbursable)
Intelsat III F-2 1968 116A	Delta	18 Dec		1436.3	35,805	35,778	0.5	87	Communications: Comsat commercial satellite scheduled to be placed in commercial service between the US and Puerto Rico. (Reimbursable)
				GEOSYNCHRONOUS ORBIT					
Apollo VIII (AS-503/ CSM-103) 1968 118A	Saturn V	21 Dec	27 Dec 68					51,655	First Manned Saturn V Flight: Frank Borman, James A. Lovell, Jr., and William A. Anders, demonstrated crew, space vehicle, and mission support facilities performance during a manned lunar orbital mission. 147 hours and 1 minute duration. Mission accomplished 10 lunar orbits returning good lunar orbit photography.
1969									1969
OSO-V (F) 1969 006A	Delta	22 Jan		95.4	550	530	32.9	281	Solar Physics: The primary objective of OSO-F is to obtain high spectral resolution data (within the 1Å - 1250Å range) from onboard solar experiments pointed toward the sun.
International Satellite for Ionospheric Studies-1(ISIS-A) 1969 009A	Delta	30 Jan		128.3	3522	580	88.4	235	Ionospheric Studies: Third mission in a series of five missions in the cooperative US/Canadian space program. (WTR)

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(Left to right) astronauts James McDivitt, David Scott, and Russel Schweichart, Apollo IX (launched March 3, 1969).



(Left to right) astronauts E. A. Cernan, J. W. Young, and Thomas P. Stafford, Apollo X (launched May 18, 1969).

NASA Major Launch Record

1969

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Intelsat III F-3 1969 011A	Delta	5 Feb		1436.4	35,807	35,778	1.3	129	Communications: 1200 - two-way circuits for voice, TV, and other commercial services; current orbit 62°E longitude; over Indian Ocean. (Comsat Reimbursable)
				GEOSYNCHRONOUS ORBIT					
Mariner VI (F) 1969 014A	Atlas-Centaur	25 Feb	11 May 71	HELIOCENTRIC ORBIT				380	Planetary/Interplanetary Exploration: Mid-course correction successfully executed to achieve a Mars flyby within 2000 miles on 31 July 69. Designed to perform investigations of atmospheric structures and compositions and to return TV photos of surface topography.
ESSA IX (TOS-G) 1969 016A	Delta	26 Feb		115.2	1507	1427	101.8	136	Meteorology: Ninth and last mission of TOS series. (Reimbursable)
Apollo IX (AS-504/ CSM-104/ LM-3) 1969 018A	Saturn V	3 Mar	13 Mar 69					51,655	First manned flight of all Manned Lunar hardware in earth orbit. James McDivitt, David Scott, and Russel Schweichart. First manned flight of Lunar Module. Successful LM active rendezvous. EVA by Schweichart for 67 minutes. Atlantic recovery postponed one orbit due to weather. 241 hours and 1 minute duration. EVA by Scott - 61 minutes.
Mariner VII (G) 1969 030A	Atlas-Centaur	27 Mar	30 Dec 70	HELIOCENTRIC ORBIT				380	Planetary/Interplanetary Exploration: Spacecraft identical to Mariner VI. Midcourse correction successful for 3518 km flyby. Flyby: 5 Aug 69.

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Nimbus III (B2) 1969 037A	Thorad-Agena	14 Apr		107	1137	1073	99.9	616	Meteorology: Carries experiments identical to those carried by Nimbus B. IRIS instrument failed after meeting objectives. (WTR).
Apollo X (AS-505/ CSM-106/ LM-4) 1969 043A	Saturn V	18 May	26 May 69					51,655	Manned lunar mission development flight to evaluate LM performance in the cislunar and lunar environment. E.A. Cernan, J. W. Young, and T. P. Stafford. Major activities: descent of LM to within 50,000 feet of lunar surface and 19 color television transmissions. Pacific splashdown. 192 hours and 3 minutes duration.
Intelsat III F-4 1969 045A	Thor-Delta	22 May		1436.3	35,801	35,780	0.5	291	Global telecommunications satellite. 174°E longitude; over Pacific Ocean. (Comsat Reimbursable)
				GEOSYNCHRONOUS ORBIT					
OGO-VI (F) 1969 051A	Thorad-Agena D	5 Jun	12 Oct 79	99.4	1068	396	82.0	632	Interdisciplinary Studies: Observatory appendage deployment, sun acquisition, and earth acquisition were completed successfully. Three-axis stabilization was achieved. Two 30-foot antennas deployed. (WTR)
Explorer XLI (IMP-G) 1969 053A	Thor-Delta	21 Jun	23 Dec 72	4842.8	175,672	1208	82.8	78	Particles and Fields: Continued study of the environment within and beyond the earth's magnetosphere during period of high solar activity. (WTR)

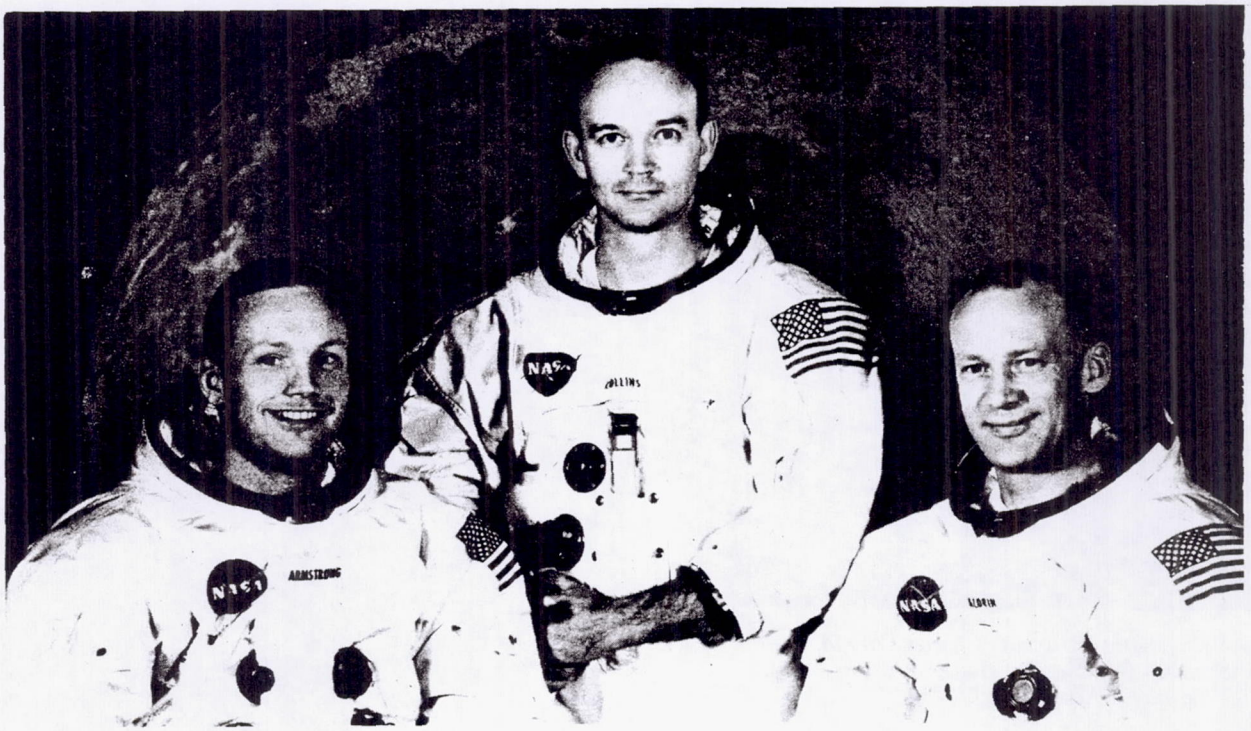
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NASA Major Launch Record 1969

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Biosatellite III (BIOS-D) 1969 056A	Delta (DSV-3N)	29 Jun	7 Jul 69	91	331	312	33.5	703	Biology: Spacecraft in orbit for 8-1/2 days with all life support parameters controlled within specification before deteriorating physiological condition of monkey required recovery of capsule. The animal, when given intensive care in the laboratory, responded initially. However, it expired suddenly about 8 hrs. later. An autopsy showed death due to heart failure brought about by problems associated with weightlessness and a lower than normal body temperature - Mission judged unsuccessful.
Apollo XI (AS-506/ CSM-107/ LM-5) 1969 059A	Saturn V	16 Jul	24 Jul 69					51,655	First manned lunar landing mission: Limited selenological inspection, photography, survey, evaluation, and sampling of the lunar soil. Assessed the capability and limitations of an astronaut and his equipment in the lunar environment. Astronauts: Neil A. Armstrong, Michael Collins, and Edwin E. Aldrin, Jr. Touchdown on lunar surface was 20 July. Pacific splashdown was 24 July, 12:51 p.m. EDT. 195 hours and 18 minutes duration.
Intelsat III F-5 1969 064A	Delta	26 Jul		146	5348	266	30.3	290	Global telecommunications satellite: To form part of a global communication, commercial satellite system. Spacecraft did *not achieve desired orbit due to third stage failure.* (Comsat Reimbursable)

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(Left to right) astronauts Neil A. Armstrong, Michael Collins, and Edwin E. Aldrin, Jr., Apollo XI (launched July 16, 1969).

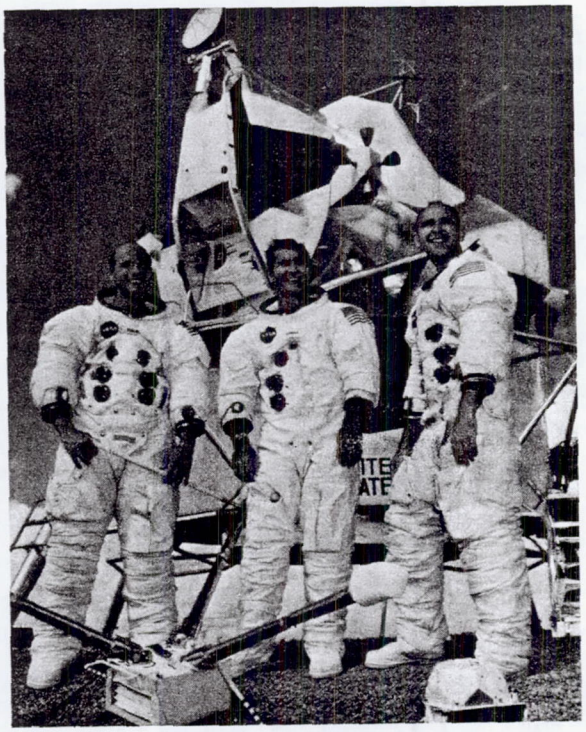


NASA Major Launch Record

1969

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
OSO-VI (G) 1969 068A	Delta	9 Aug		95	551	489	32.9	289	Solar Physics: The primary objective of OSO-G is to obtain high spectral resolution data (within the 10 to 20 Kev and 1Å to 1300 Å range) from onboard solar experiments pointed toward the sun.
ATS-V (E) 1969 069A	Atlas-Centaur	12 Aug		1435.9	35,790	35,777	2.5	431	Application and Technology: To conduct a carefully instrumented gravity gradient orientation experiment directed toward providing the basic design information for the stabilization and control of long-lived spacecraft in synchronous orbit. Mission unsuccessful due to inability to perform primary objective of the gravity gradient experiment.
					GEOSYNCHRONOUS ORBIT				
Pioneer E	Delta	27 Aug	27 Aug 69					66	To obtain polar plasma, magnetic field, and cosmic-ray measurements near the orbital path of the earth but outside the earth's region of influence. This was the fifth and last launch of current Pioneer series. Launch vehicle destroyed by Range Safety Officer after 8 min. 2 sec.
Boreas ESRO-IB 1969 083A	Scout	1 Oct	23 Nov 69	90	311	267	85.1	85	ESRO-IB is the second satellite of the ESRO-I Project. The satellites are designed to study ionospheric and auroral phenomena particularly over the northern polar regions in darkness in the winter. Carried eight experiments. (WTR)(Reimbursable)

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(Left to right) astronauts Charles Conrad, Jr., Richard F. Gordon, Jr., and Alan Bean, Apollo XII (launched November 14, 1969).

NASA Major Launch Record

1969

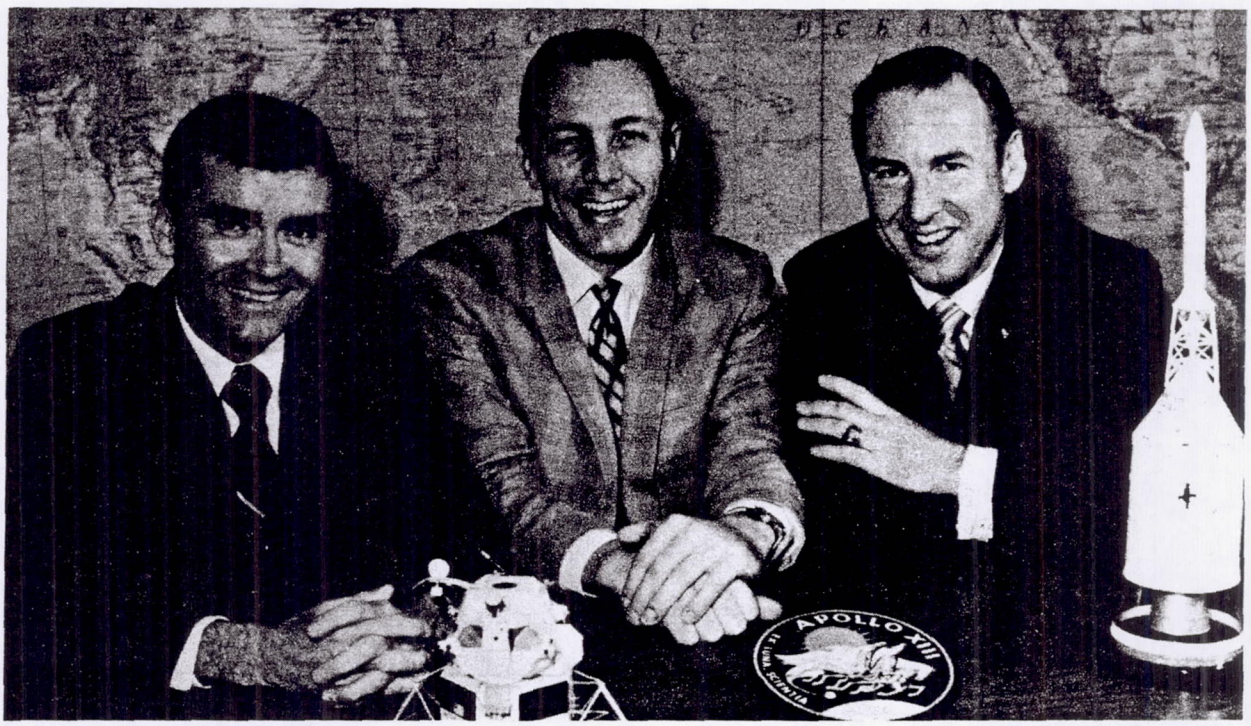
MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	
German Research Satellite-A (AZUR) 1969 097A	Scout	8 Nov		121.9	3149	386	102.9	72	Particles and Fields: Study of the inner Van Allen belt, the auroral zones of the Northern Hemisphere, and the spectral variations of solar particles versus time during solar flares. (WTR) (International Cooperative)
Apollo XII (AS-507/ CSM-108/ LM-6) 1969 099A	Saturn V	14 Nov	24 Nov 69					51,655	Second manned lunar landing mission: Demonstrated point landing capability, sampled mare area, deployed ALSEP, investigated the Surveyor III spacecraft, and obtained photographs of candidate exploration sites. Astronauts: Charles Conrad, Jr., Richard F. Gordon, Jr., and Alan Bean. Touchdown on lunar surface was 19 November. Total EVA time was 15 hours 32 minutes.
Skynet-A 1969 101A	Delta	22 Nov		1436	35,820	35,749	3.8	242	Communications: Equatorial synchronous satellite located over Indian Ocean. (International Reimbursable)
				GEOSYNCHRONOUS ORBIT					

1970

Intelsat III F-6 1970 003A	Delta	14 Jan		1436	35,788	35,780	0.9	293	Global telecommunications satellite: To form part of a global communication, commercial satellite system. (Reimbursable)
				GEOSYNCHRONOUS ORBIT					
ITOS-1 (Tiros-M) 1970 008A	Delta	23 Jan		115	1479	1433	101.99	306	Meteorology: Second generation operational met. satellite carried TV, automatic picture transmission and scanning radiometers for global cloud data for remote and local readout both day and night. First launch of the Delta with 6 solid strap-ons. (OSCAR ham radio sat. launched from the Delta in orbit). Deactivated by NOAA on 17 Jun 71.

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
SERT-II 1970 009A	Thor-Agena	4 Feb		105	1007	995	99.13	503	Ion Engine Test: Demonstrate the capability of an electric ion thruster system to operate 6 months in space. Mission unsuccessful because it operated short of its full duration due to electrical shortage in its high voltage system. (WTR)
NATOSAT-I (NATO-A) 1970 021A	Delta	20 Mar		1436	35,822	35,750	3.0	242	Communications Satellite: To place a military communications satellite into a stationary equatorial orbit. (International Reimbursable)
				GEOSYNCHRONOUS ORBIT					
Nimbus IV (D) 1970 025A	Thor-Agena	8 Apr		107.27	1108	1092	80.114	619	Meteorology: Fifth in a series of seven advanced research and development weather satellites. Seven of 9 experiments are operational.
Apollo XIII (AS-508/ CSM-109/ LM-7) 1970 029A	Saturn V	11 Apr	17 Apr 70					51,655	Third manned lunar landing attempt aborted after 56 hours GET due to loss of pressure in liquid oxygen in Service Module and the failure of fuel cells 1 and 3. Astronauts: James A. Lovell, Jr., Fred W. Haise, Jr., and John L. Swigert, Jr. Total flight time was 142 hours 55 minutes. Splashdown occurred in Pacific Ocean.
Intelsat III F-7 1970 032A	Delta	22 Apr		Current Elements Not Maintained				290	Global Telecommunications Satellite: To form part of a global communication, commercial satellite system. (Comsat Reimbursable)
									1 lb = 0.4536 kg 1 mi = 1.609 kg 1 NM = 1.8515 kg



(Left to right) Astronauts James A. Lovell, Jr., Fred W. Haise, Jr., and John L. Swigert, Jr., Apollo XIII (launched April 11, 1970).

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	
Intelsat III F-8 1970 055A	Delta	23 Jul		ORBIT NOT ACHIEVED				290	Global Telecommunications Satellite: To form part of a global communication, commercial satellite system. Last launch for the Intelsat III series spacecraft. Did not orbit. (Comsat Reimbursable)
Skynet 2 (IDCSP/A) 1970 062A	Delta	19 Aug		ORBIT NOT ACHIEVED				242	UK Communications Satellite - Vehicle Failed (Reimbursable)
RAM C-3 (C)	Scout	30 Sep						134	Compare the effectiveness of a liquid electrophilic (Freon) with water in alleviating radio blackout during a 25,000 fps reentry.
OFO-1 (A) 1970 094A (RMS) 1970 094B	Scout	9 Nov 9 Nov	9 May 71 7 Feb 71	93	574	300	37.7	132	Obtain direct measurements of the (vestibular nerve) activity changes and study the adaptation of the otolith system (in two bull frogs) under conditions of weightlessness and acceleration. Vehicle also carried secondary payload: Radiation/Meteoroid Satellite (RMS); RMS remained attached to Scout 4th stage.
OAO-B	Atlas-Centaur	30 Nov	30 Nov 71	ORBIT NOT ACHIEVED				2121	To obtain moderate resolution spectrophotometric data in ultraviolet bands between 1100 and 4000Å; to investigate photometry of peculiar stars, the law of interstellar reddening, magnitude and intensity of Lyman-alpha red shift for nearby galaxies, spectra of emission and reflection nebulae. Nose fairing separation system failed to separate at proper time. (Vehicle failure)

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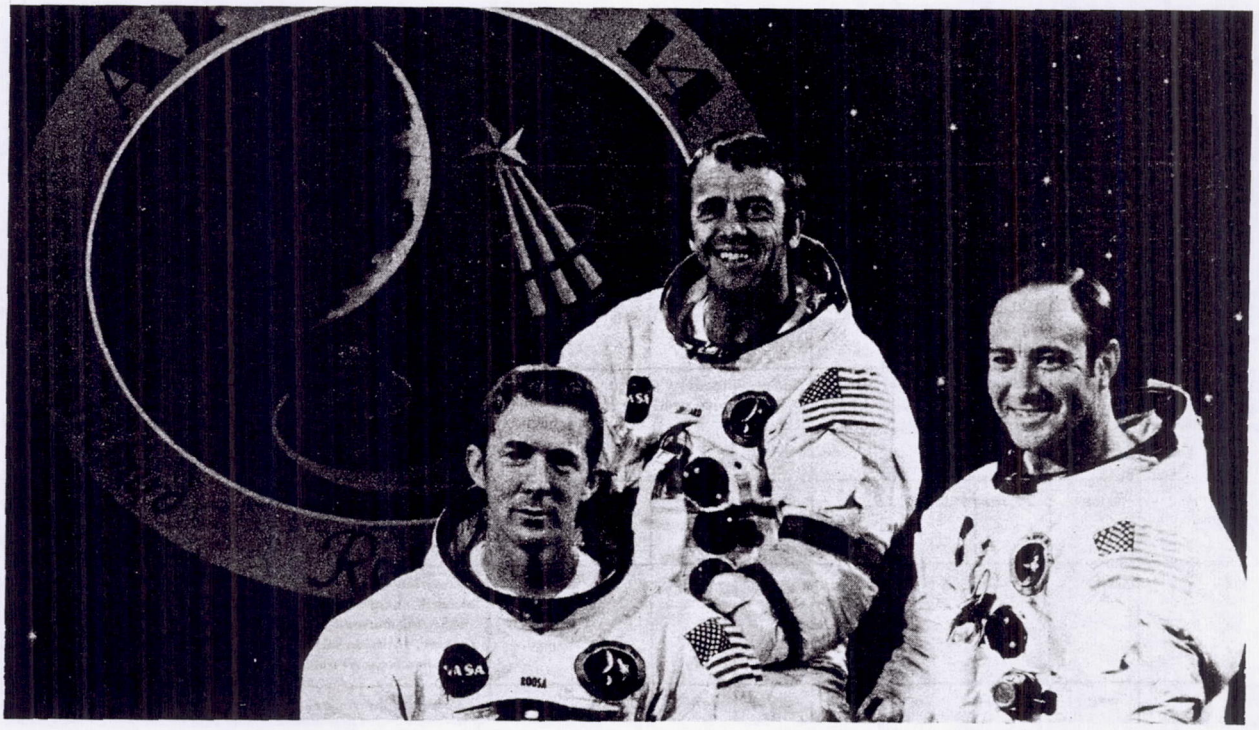
NASA Major Launch Record 1970

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	
ITOS-A (NOAA-1) 1970 106A	Delta	11 Dec		115	1472	1422	101.9	309	To conduct in-orbit engineering evaluation so that the daytime and nighttime cloud-cover observations can be obtained regularly and dependably in both direct readout and stored modes of operation. A Cylindrical Electrostatic Probe Experiment (CEPE) was carried as a piggyback, permanently attached to the Delta second stage. Deactivated by NOAA on 19 Aug 71. (Reimbursable)
SAS-A (Explorer 42) 1970 107A	Scout	12 Dec	5 Apr 79	96	572	531	3.0	145	To develop a catalog of celestial X-ray sources by systematic scanning of the celestial sphere in the energy range 2-20 KEV. First orbiting X-ray satellite. (SM)

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MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
Name Desig	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	
Intelsat IV F-2 1971 006A	Atlas-Centaur	25 Jan		1436.2	35,802	35,776	0.2	1383	Global Telecommunications Satellite: To form part of a global communication commercial satellite system. First launch of the Intelsat IV series. (COMSAT Reimbursable)
				GEOSYNCHRONOUS ORBIT					
Apollo 14 (AS-509/CSM-110/LM-8) 1971 008A	Saturn V	31 Jan	9 Feb 71					51,655	Third manned lunar landing. Astronauts: Alan B. Shepard, Stuart A. Roosa, and Edgar D. Mitchell. Total flight time was 216 hrs 02 min. Splashdown occurred in Pacific Ocean on 9 Feb 71.
NATO-B (NATOSAT-2) 1971 009A	Delta	2 Feb		GEOSYNCHRONOUS ORBIT				243	Communications Satellite: To place a military communications satellite into a stationary equatorial orbit. (NATO) Reimbursable
IMP-I (Explorer 43) 1971 019A	Delta	13 Mar	2 Oct 74	5967.1	196,124	9073	37.2	224	To extend our knowledge of solar-lunar-terrestrial relationships by conducting a continuing study of the radiation environment of the interplanetary magnetic field and its dynamical relationship with solar particles.
ISIS-B (ISIS-2) (Canadian) 1971 024A	Delta	31 Mar		113.6	1427	1359	88.1	240	To study electron production and loss and large scale transport of ionization in the ionosphere. WTR (International Cooperative)
San Marco-C (3) (Italian) 1971 036A	Scout	24 Apr	29 Nov 71	94.1	722	222	3.2	159	To investigate and define the equatorial neutral particle atmosphere in terms of density, composition, and temperature behavior and variations resulting from solar and geomagnetic activities. Vehicle provided by NASA on non-reimbursable basis. Launched from San Marco Range.

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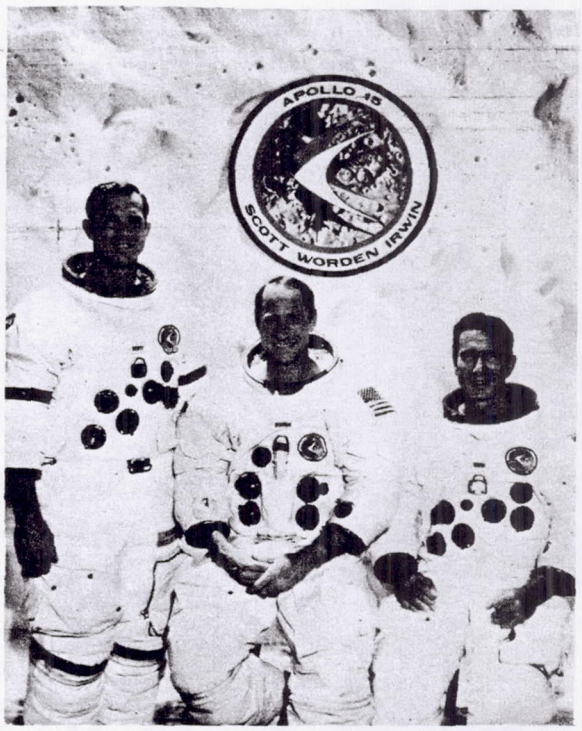


(Left to right) astronauts Stuart A. Roosa, Alan B. Shepard, and Edgar D. Mitchell, Apollo XIV (launched January 31, 1971).

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Mariner Mars 71 Mariner H (8) Mariner I (9) 1971 051A	 A-Centaur A-Centaur	 8 May 30 May	 8 May 71	 AREOCENTRIC ORBIT	 Apoapsis 17,125	 Periapsis 1400	 	 1029 1030	To study the dynamic characteristics of the planet Mars from orbit for a minimum period of 90 days also to map approximately 70% of the planet. Mariner 8 failed because of vehicle malfuction. Mariner 9 entered Mars orbit on 13 Nov. 71. It responded to 37,764 commands and transmitted 6, 876 pictures of the Mars surface. All scientific instuments operated successfully. Mariner 9 terminated as of 6:31 pm, EDT, 27 Oct 72.
Planetary Atmosphere Experiment Test	Scout	20 Jun		14				134	Demonstrate the ability to determine the structure and composition of the atmosphere through onboard instrumentation from a probe vehicle entering the atmosphere at high speed (25,000 fps.). Launched from Wallops Island.
SOLRAD-10 (NRL)(Explorer 44) 1971 058A	Scout	8 Jul		95.2	627	433	51.0	52	To monitor the sun's X-ray and ultraviolet emissions in order to better understand the solar physical processes and to improve the prediction techniques of solar activity and ionospheric disturbances. Vehicle provided by NASA on non-reimbursable basis. Launched from Wallops Island.
Apollo 15 (AS-510/CSM-112/LM-10) 1971 063A	Saturn V	26 Jul	7 Aug 71	SELENOCENTRIC ORBIT				51,655	Fourth manned lunar landing and first of Apollo "J" series missions which carry Lunar Roving Vehicle. Astronauts: David R. Scott, Alfred M. Worden, and James Bensen Irwin. Total flight time was 295 hrs, 12 minutes. Total EVA time was 18 hrs, 46 min. Worden's in-flight EVA was 38 min, 12 sec performed out-of-earth orbit. Splashdown in Pacific about 288 nautical miles due north of Pearl Harbor.
									1 lb = 0.4536 kg 1 mi = 1.609 km 1 NM = 1.8515 km

NASA Major Launch Record 1971

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Coop. Appl. Sat. CAS-A/EOLE-1 (France) 1971 071A	Scout	16 Aug		100.6	906	677	50.1	98	Data Collection: Cooperation of the United States with France in a Space Meteorology Project using instrumented balloons and an earth orbiting satellite to obtain in-situ speed and direction of winds (air masses) at various altitudes. Launched from Wallops Island.
Barium Ion Cloud (GRS-B) (German)	Scout	20 Sep			Barium Release at 5 RE at 9 N. Latitude and 78 W Longitude			32	A joint NASA/German effort to study the broad features of electric and magnetic fields in the outer radiation belt by optical investigation of the behavior of a barium ion cloud released at several earth radii altitude. Vehicle provided by NASA on non-reimbursable basis. Launched from Wallops Island.
OSO-H (7) 1971 083A	Delta	29 Sep	9 Jul 74	93.5	564	327	33.1	635	To observe the active physical processes on the sun by which the sun influences the earth and its space environment; and to advance our understanding of the sun's constitution and behavior.
ITOS-B	Delta	21 Oct		ORBIT NOT ACHIEVED				317	To provide improved operational infrared and visual observations of earth cloud cover for use in weather analysis and forecasting. NASA reimbursed by NOAA for both spacecraft and launch support. Mission failure due to vehicle second stage malfunction. Launched from Western Test Range. (Reimbursable)
SSS-A (Explorer 45) 1971 096A	Scout	15 Nov		465.4	26,783	247	3.5	44	Investigate the ring-current and magnetic storms; relations between auroral phenomena, magnetic storms, and the acceleration of charged particles within the inner magnetosphere; and time variations of the particle population. Launched from San Marco.
									1 lb = 0.4536 kg 1 mi = 1.609 km 1 NM = 1.8515 km



(Left to right) astronauts David R. Scott, Alfred M. Worden, and James Bensen Irwin, Apollo XV (launched July 26, 1971).

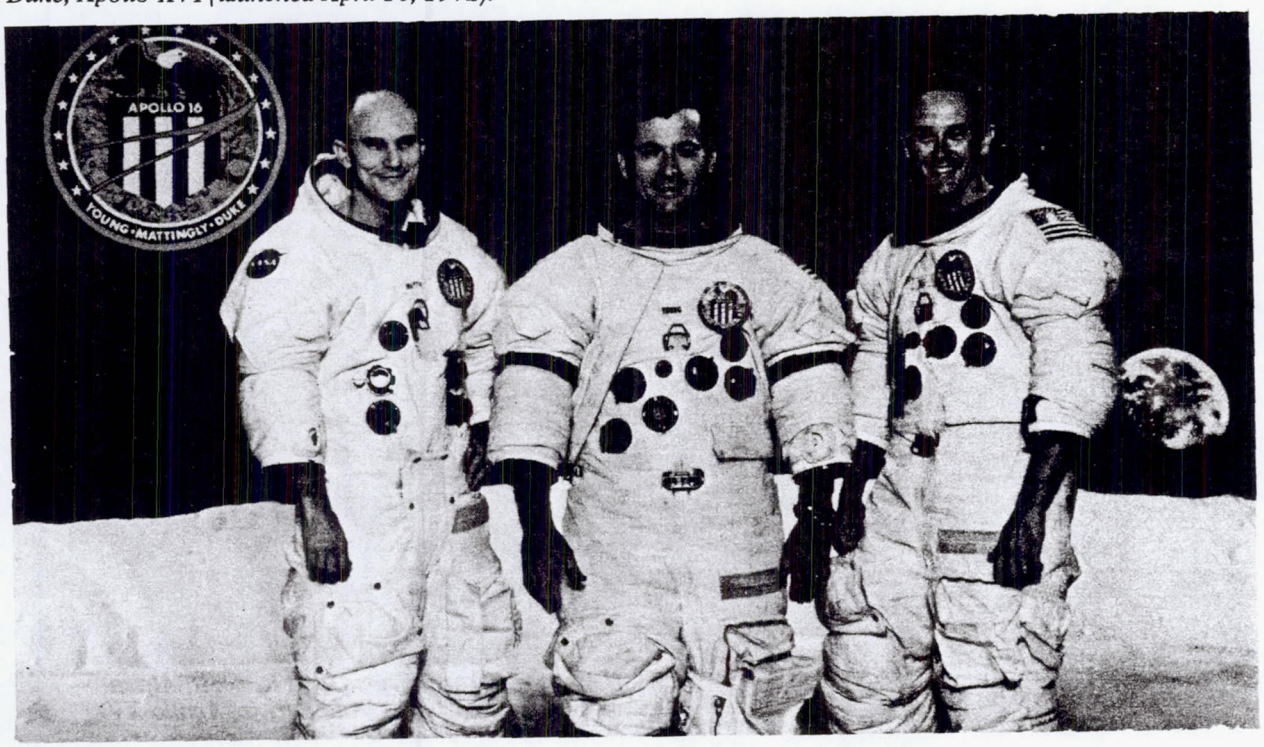
NASA Major Launch Record

1971

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
UK-4 (United Kingdom) 1971 109A	Scout	11 Dec	12 Dec 78	95.2	591	476	82.9	101	Investigate interactions among the plasma, charged particle streams, and electromagnetic waves in the upper ionosphere. Launched from Western Test Range. (International Cooperative)
Intelsat IV F-3 1971 116A	A-Centaur	19 Dec		1436.2	35,827	35,750	0.4	1397	Global commercial communications satellite system. (Comsat Reimbursable)
					GEOSYNCHRONOUS ORBIT				

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(Left to right) astronauts T.K. Mattingly II, J. W. Young, and C.M. Duke, Apollo XVI (launched April 16, 1972).



NASA Major Launch Record

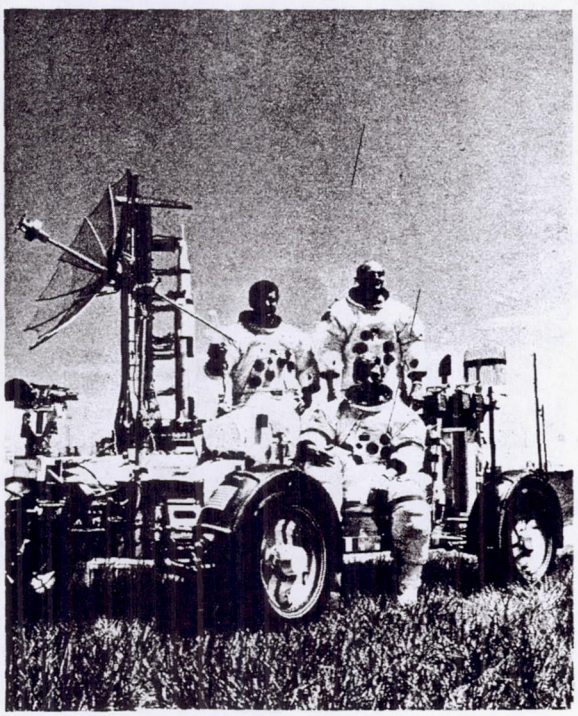
1972

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	
Intelsat IV F-4 1972 003A	A-Centaur	22 Jan		1436	35,805	35,772	0.0	1397	Global commercial communications satellite system. (Comsat Reimbursable)
					GEOSYNCHRONOUS ORBIT				
HEOS A-2 1972 005A	Delta	31 Jan	2 Aug 74	7493	235,691	5269	88.46	123	*Investigation of Interplanetary Space and of the high latitude magnetosphere and its boundary in the region around the northern neutral point.* (ESRO Reimbursable)
Pioneer-F (10) 1972 012A	A-Centaur	3 Mar			SOLAR SYSTEM ESCAPE TRAJECTORY			257.64	Investigation of the interplanetary medium; the nature of the asteroid belt; and the exploration of Jupiter and its environment.
TD-1 (ESRO) 1972 014A	T-Delta	12 Mar		95	539	531	97.5	472	NASA responsible for placing satellite in an earth orbit for ESRO. Seven scientific experiments are onboard the spacecraft. (Reimbursable)
Apollo 16 (AS-511/CSM-113/LM-11) 1972 031A	Saturn V	16 Apr	27 Apr 72					51,655	Fifth manned lunar landing and second of the Apollo "J" series which carry the Lunar Roving Vehicle. Astronauts: J.W. Young, T.K. *Mattingly II and* C. M. Duke. Total flight time was 265 hours 51 minutes. Total EVA time was 20 hours 14 minutes. Mattingly's in-flight EVA was 1 hour 24 minutes. Splashdown in Pacific Ocean. Recovery ship was U.S.S.Ticonderoga. Estimated amount of samples returned for scientific study approximately 213 lbs.
Intelsat IV-F-5 1972 041A	A-Centaur	13 Jun		1436	35,792	35,783	0.1	719	Global commercial communications satellite system. (Comsat Reimbursable)
					GEOSYNCHRONOUS ORBIT				

1 lb = 0.4536 kg 1 mi = 1.609 km 1 NM = 1.8515 km

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
ERTS-A (1) 1972 058A	Delta	23 Jul		103.29	915	899	99.1	816.48	Acquire synoptic, multispectral repetitive images to investigat disciplines, i.e., agriculture, forestry, mineral and land resources, land use, water and marine resources, map and chart. (WTR)
MTS (Explorer 46) 1972 061A	Scout	13 Aug		97.84	822.6	503.9	37.7	136.08	To measure the meteoroid penetration rates in a bumper protected target and to obtain meteoroid velocity and impact flux data. (WI)
OAO-3 Copernicus 1972 065A	Atlas-Centaur	21 Aug		99.66	745	740	35.0	2204	To obtain precise astronomical observations of celestial objects from above the earth's atmosphere so that new and fundamental knowledge about the universe may be acquired.
Transit (INS-1) 1972 069A	Scout	2 Sep		100.7	839	742	90.1	93.6	US Navy Navigation Satellite (WTR) (Reimbursable)
IMP-H (Explorer 47) 1972 073A	Delta	22 Sep		17,702.1	235,639	201,599	17.2	376	To study cislunar radiation environment over significant portion of solar cycle, interplanetary magnetic field and earth's magnetosphere.
ITOS-D (NOAA-2) 1972 082A AMSAT-OSCAR-6 (Sub-Sat.) 1972 082B	Delta	15 Oct		115	1453	1448	101.8	344	An operational meteorological satellite based on Tiros research and development experience. A small communications relay satellite (AMSAT-OSCAR-C) designed to operate in the radio amateur frequency bands was carried as a piggyback. Design life of the A-O-C is at least 1 yr. of successful operation in orbit. (Reimbursable)

(Left to right) astronauts Harrison Schmitt, Ron Evans, and Gene Cernan, Apollo XVII (launched December 7, 1972).



MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Telesat-A (ANIK) 1972 090A	Delta	9 Nov		1436	36,803	35,774	0.1	557.1	First of a series of Canadian Domestic Communications Satellites. It has been designed to provide transmission of television, voice, data, etc. throughout Canada. (Reimbursable)
				GEOSYNCHRONOUS ORBIT					
SAS-B (Expl. 48) 1972 091A	Scout	16 Nov		95.4	632	443	1.9	185	To perform a sky survey of high energy gamma radiation from the celestial spheres, to determine the extent of primary galactic gamma radiation and to ascertain the presence of gamma ray point sources.
		(Launched by Italy for NASA from San Marco Range Facility.)							
ESRO-IV 1972 092A	Scout	21 Nov	15 Apr 74	99.0	1187	253	91.1	114.8	Investigate and measure several phenomena in the polar ionosphere. (Reimbursable) WTR
Apollo 17 (AS-512/CSM-114/LM-12) 1972 096A	Saturn V	7 Dec	19 Dec 72					51,655	Sixth and last manned lunar landing; third of the Apollo "J" series which carried the lunar rover. Flight crew E.A. Cernan (CDR), R.E. Evans (CMP), H.H. Schmitt (LMP) spent 301 hrs 52 mins. in flight. Cernan and Schmitt during the three EVAs completed a total of 22 hrs 4 min. each. The U.S.S. Ticonderoga recovered the crew and approximately 250 lbs of samples.
Nimbus E (5) 1972 097A	Delta	11 Dec		107.3	1103	1102	99.94	772	A stabilized earth-oriented platform for the testing of advanced systems, sensing, and collecting meteorological and geological data.
AEROS (German A-2) 1972 100A	Scout	16 Dec	22 Aug 73	95	864	218	96.95	125	Study the state and behavior of the upper atmosphere and ionospheric F region, especially with regard to the influence of solar ultraviolet radiation. (WTR) (International Cooperative)

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(Left to right) astronauts Joseph P. Kerwin, Charles Conrad, Jr., and Paul J. Weitz, first manned visit, Skylab II (launched May 25, 1973).

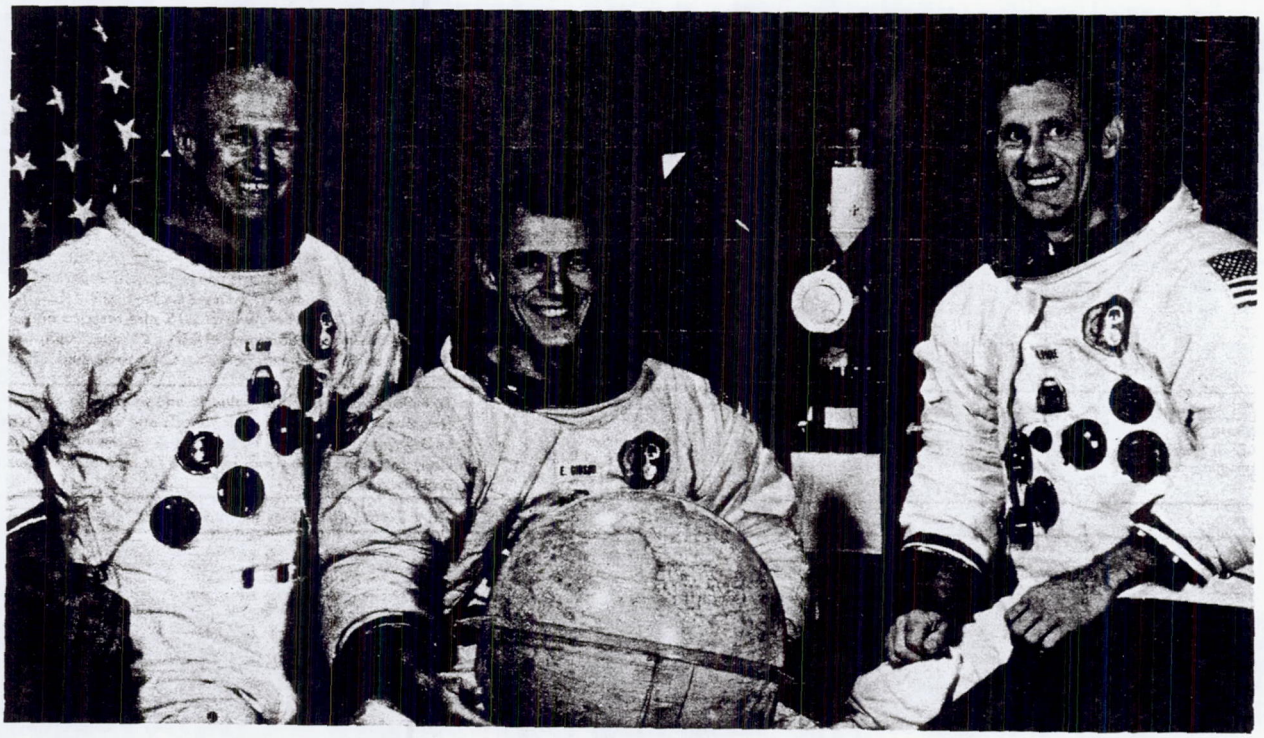
MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Pioneer G (11) 1973-019A	A-Centaur	6 Apr		HELIOCENTRIC ORBIT			34.9	259	To obtain precursory scientific information beyond the orbit of Mars with the following emphasis: (a) investigation of the interplanetary medium; (b) investigation of the nature of the asteroid belt; (c) exploration of Jupiter and its environment.
Telesat-B (ANIK-2) 1973-023A	Delta	20 Apr		1436	35,800	35,776	0.0	560	Second of a series of Canadian Domestic Communication Satellites. Designed to transmit TV, voice, data. (Reimbursable)
				GEOSYNCHRONOUS ORBIT					
Workshop SL-1 513/SIVB-212 1973-027A	Saturn V	14 May	11 Jul 79	93.4	440	427	50.0	71,500	Unmanned - Spacecraft is comprised of an Orbital Workshop (OWS), Airlock Module (AM), Multiple Docking Adapter(MDA), Apollo Telescope Mount (ATM), Instrument Unit (IU), and Payload Shroud (PS).
First Manned Visit SL-2 206/CSM-116 1973 032A	Saturn IB	25 May	22 Jun 73	93.2	440	425	50.0	29,750	First Manned Skylab launch. Crew: Charles Conrad, Jr., (CDR); Science Test Pilot, Joseph P. Kerwin; Pilot, Paul J. Weitz. Objectives: Establish the Skylab Orbital Assembly in earth orbit, and conduct a series of medical experiments associated with the extension of manned space flight. USS Ticonderoga recovered SL-2 from the Pacific 38.5 mins after landing. Duration of mission was 28 days, 49 mins, 49 secs. Data was obtained on 46 of 55 experiments. Crew performed 3 EVA's.
Radio Astronomy Explorer B (RAE-B) (Expl.49) 1973-039A	Delta	10 Jun		LUNAR TRANSFER TRAJECTORY				328	To make measurements of galactic and solar radio noise at frequencies below ionospheric cutoffs and external to terrestrial background interference by utilization of the moon for occultation, focusing, or aperture blocking for increased resolution and discrimination.

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(Left to right) Dr. Owen K. Garriot, Jack R. Lousma, and Alan L. Bean, second manned visit, Skylab III (launched July 28, 1973).

(Left to right) astronauts Gerald P. Carr, Edward G. Gibson, and William R. Pogue, third manned visit, Skylab IV (launched November 16, 1973).



NASA Major Launch Record

1973

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
ITOS-E (NOAA)	Delta	16 July	16 July	ORBIT NOT ACHIEVED				345	Operational meteorological satellite to obtain global cloud-cover data both day and night for use in weather analysis and forecasting. NASA reimbursed by NOAA for both spacecraft and launch support. Mission failed due to vehicle second stage malfunction. Launched from Western Test Range.
Second Manned Visit SL-3 207/CSM-117 1973 - 050A	Saturn IB	28 July	25 Sep	93.2	440	423	50.0	29,750	Second Manned Skylab launch. Crew: Alan L. Bean, (CDR); Science Pilot, Owen K. Garriot; Pilot, Jack Robert Lousma. The crew performed systems and operational tests, assigned experiments, and thermal shield deployment. USS New Orleans recovered SL-3 from Pacific Ocean 43 mins. after splashdown. Mission duration was 59 days, 11 hrs, 9 min, 4 sec. Crew performed 3 EVAs.
Intelsat IV F-7 1973 - 058A	A-Centaur	23 Aug		640	31,233	474	27.3	1112.2	Global commercial communications satellite system. (Reimbursable)
IMP-J (Exp. 50) 1973-078A	Delta	25 Oct		17,279	281,500	268,900	28.7	371	To perform detailed and near continuous studies of the interplanetary environment for orbital periods comparable to several rotations of active solar regions; and to study particle and field interactions in the distant magnetotail including cross sectional mapping of the tail and neutral sheet.
Transit(NNSS/ 0-20) 1973-081A	Scout	30 Oct		105.6	1153	891	90.2	95	US Navy Navigation Satellite (WTR) (Reimbursable)

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NASA Major Launch Record

1973

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Mariner/Venus/ Mercury-J 1973 - 085-A	A-Centaur	3 Nov		HELIOCENTRIC ORBIT				504	To conduct exploratory investigations of the planet Mercury by obtaining measurements of its environment, atmosphere, surface, and body characteristics, and to conduct similar investigations of Venus during its flyby. First priority is assigned to Mercury investigations.
ITOS-F (NOAA-3) 1973 - 086A	Delta	6 Nov		116	1512	1504	101.8	340	Operational Meteorological Satellite to obtain global cloud-cover data both day and night for use in weather analysis and forcasting. NASA is reimbursed by NOAA for both spacecraft and launch support. (WTR) (Reimbursable)
				SUN SYNCHRONOUS					
Third Manned Visit SL-4 208/CSM-118 1973-090A	Saturn IB	16 Nov	8 Feb 74	90.0	430	450	50	29,750	Third Manned Skylab launch. Crew: Gerald Carr, commander; Edward Gibson, science pilot; William Pogue, pilot. To perform unmanned Saturn Workshop operations; reactivate the Skylab orbital assembly in earth orbit; obtain medical data on the crew for use in extending the duration of manned space flights; perform inflight experiments. USS New Orleans recovered SL-4 from Pacific Ocean appox. 40 mins. after splashdown. Mission duration was 84 days, 1 hr, 16 min. Crew performed 4 EVA's.
Atmosphere Expl.-C (Expl. 51) 1973 - 101A	Delta	16 Dec	12 Dec 78	132.5	4300	154	68.1	663	To investigate the photochemical processes accompanying the absorption of solar ultraviolet radiation in the Earth's atmosphere by making closely coordinated measurements of the reacting constituents from a spacecraft with onboard propulsion to permit perigee and apogee altitudes to be varied by command.

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NASA Major Launch Record

1974

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Skynet II-A 1974-002A	Delta	18 Jan		106.6	2009	126	37.5	435	United Kingdom Communications Satellite - Vehicle failed due to a short circuit in the electronics package of the vehicle. (Reimbursable)
Centaur Proof	Titan III E Centaur	11 Feb	11 Feb	ORBIT NOT ACHIEVED					To demonstrate the capability of the Titan III E Centaur D-1T launch vehicle, the Centaur Standard Shroud and the ability of the Integrate, Transfer Launch Facility to support operational Titan/Centaur missions. (Vehicle failure)
San Marco C-2 (San Marco-4) 1974-009A	Scout	18 Feb	4 May 76	96	930.5	234.5	2.9	170	To obtain measurements of the diurnal variations of the equatorial neutral atmosphere density, composition, and temperature. (SM) (International Cooperative)
UK-X4 1974 013A	Scout	8 Mar		101.1	926.8	727.7	97.8	92	To demonstrate an accuracy of better than 3 arc minutes using a gas jet system; to measure the performance in orbit of components of an operational infrared sensor; to check photometric calibration of the sensor to measure the density of sun-reflecting particles near the spacecraft. (WTR) (Reimbursable)
WESTAR-A (Western Union) 1974-022A	Delta	13 Apr		1415.3	35,592	35,166	.6	572	Domestic Communications Satellite to provide transmission of communications throughout the USA. (Reimbursable)
				GEOSYNCHRONOUS ORBIT					

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NASA Major Launch Record

1974

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
SMS-A (1) 1974-033A	Delta	17 May		1309.8	35,445	31,109	1.8	243	Part of a global network of geostationary environmental satellites with the objective of providing earth imaging in the visible and IR spectrums, monitoring space environment.
					GEOSYNCHRONOUS ORBIT				
ATS-F (6) 1974-39A	Titan III C	30 May		1436	35,808	35,768	0.7	1179	Applications Technology Satellite to provide a large antenna structure capable of providing good quality TV signal to small, inexpensive ground receivers.
					GEOSYNCHRONOUS ORBIT				
HAWKEYE (Explorer 52) 1974-40A	Scout	3 Jun	28 Apr 78	3032	125,570	470	89	30.8	To study the plasma properties of the magnetosphere in the vicinity of the magnetic neutral point over the Earth's north polar cap. (WTR)
AEROS-B (2) 1974-055A	Scout	16 Jul	25 Sept 75	94.8	807	220	97.4	125	To measure the main aeronomic parameters determining the state of the upper atmosphere and the solar ultraviolet radiation in the wavelength band of main absorption. (WTR) (Germany - Reimbursable)
ANS-A (1) 1974-070A	Scout	30 Aug	14 Jun 77	99.0	1,167	254	98.1	128	Obtain specral distribution and other data from celestial X-ray and ultraviolet sources (cooperative program with the Netherlands). (WTR)
WESTAR-B (2) 1974-075A	Delta	10 Oct		1436	35,790	35,783	0.0	572	Domestic Communications Satellite - Reimbursed and operated by Western Union.
					GEOSYNCHRONOUS ORBIT				

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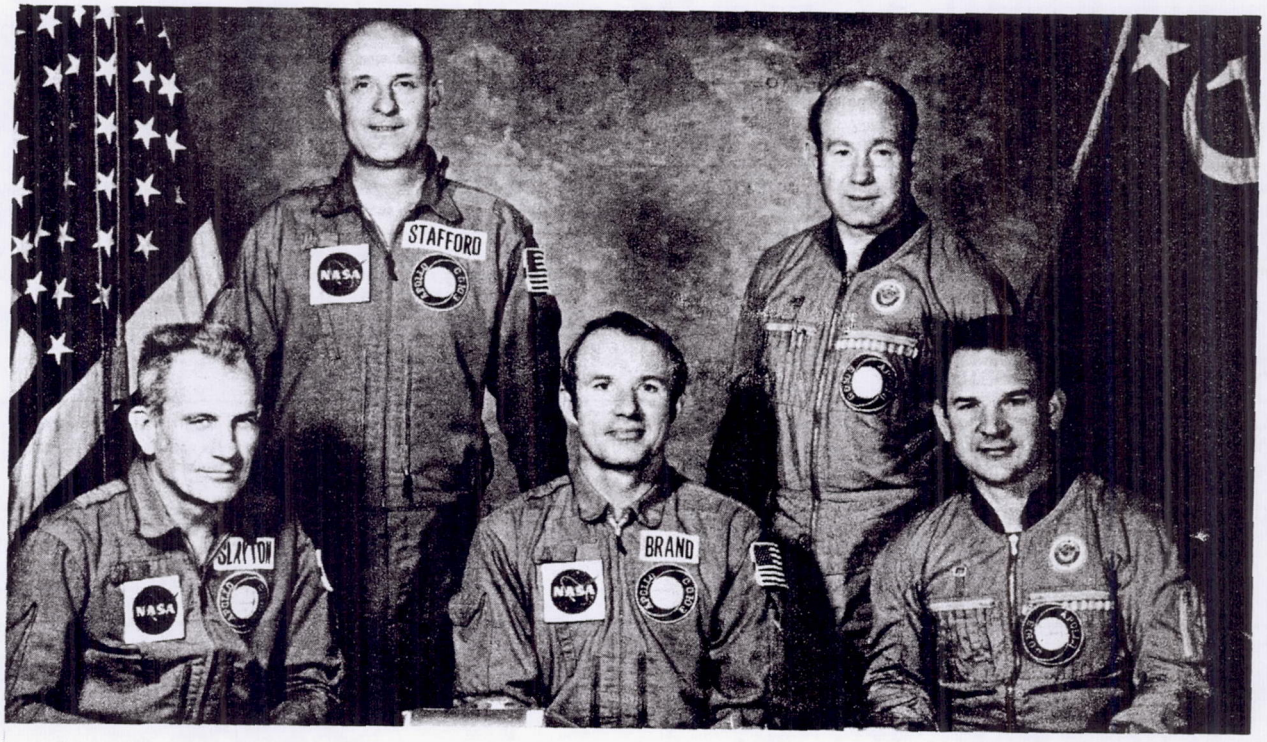
NASA Major Launch Record

1974

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted).
UK-5 (AERIEL 5) 1974-077A	Scout	15 Oct		95.4	569.5	502.0	2.86	129	To investigate galactic and extragalactic X-ray sources. (SM) (International Cooperative)
TOS-G (NOAA-4) 1974-89A	Delta	15 Nov		115	1458	1444	101.74	345	Meteorological Satellite: Constructed and launched by NASA. Reimbursed and operated by NOAA. (WTR)
INTASAT (Piggyback on TOS-G) 1974-89C				114.8	1468	1468	101.7	15	Scientific Satellite: To measure total electron content, ionospheric irregulatorities and ionospheric scintillations. Cooperative with Spain.
INTELSAT IV F-8 1974-93A	A-Centaur	21 Nov		1436	35,796	35,776	0.4	1393	Communications Satellite: Reimbursed and operated by Comsat to expand the global satellite system.
					GEOSYNCHRONOUS ORBIT				
SKYNET II-B (UK) 1974-94A	Delta	22 Nov		1436	35,781	35,762	0.8	435	Communications Satellite: United Kingdom reimbursable to provide X-Band military communications.
					GEOSYNCHRONOUS ORBIT				
Helios-A 1974-097A	Titan III-E Centaur	10 Dec			HELIOCENTRIC ORBIT			370	Scientific Satellite: To investigate the properties of and processes in interplanetary space in the direction of and close to the Sun. Cooperative with West Germany.
Symphonie-A 1974-101A	Delta	17 Dec		1436	35,801	35,772	0.4	402	Communications Satellite: Joint project by France and Germany to provide communications to Europe, Africa, and South America. Reimbursable.
					GEOSYNCHRONOUS ORBIT				

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(Left to right, standing) astronauts Thomas P. Stafford, U.S.A.; Cosmonaut Aledsey A. Leonov, U.S.S.R. (seated), Astronauts Donald K. Slayton, Vance D. Brand, U.S.A., and Cosmonaut Valerly N. Kubasov, U.S.S.R., Apollo-Soyuz test project (launched July 15, 1975).



NASA Major Launch Record

1975

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
LANDSAT-2 (Formerly ERTS) 1975-004A	Delta	22 Jan		103.32	918.23	912.89	99.090	953	Second Earth Resources Technology Satellite to locate, map, and measure earth resources parameters from space and demonstrate the applicability of this approach to the management of the worlds resources. WTR
SMS-B (2) 1975-011A	Delta	6 Feb		1436	35,801	35,776	0.1	319	Second developmental meteorological satellite to provide continuous observation of environmental phenomena and help develop an environmental network for routine observations and early warning.
				GEOSYNCHRONOUS ORBIT					
INTELSAT IV F6	A-Centaur	20 Feb		ORBIT NOT ACHIEVED					Vehicle Failure - COMSAT Communications Sat (Reimbursable)
GEOS-C (3) 1975-027A	Delta	9 Apr		101.9	844	837	115.0	340	Oceanographic and geodetic satellite to measure ocean topography, sea state, and other features of the earth. WTR
SAS-C (Expl. 53) 1975-037A	Scout	7 May	9 Apr 79	94.9	523	502	2.9	196	Scientific satellite: To search for source radiating in the X-ray, gamma ray, ultraviolet, and other spectral regions both inside and beyond our galaxy. San Marco
Telesat-C(ANIK3) 1975-038A	Delta	7 May		1436	35,793	35,783	0.0	272	Canadian Domestic Communications Satellite - Reimbursable
				GEOSYNCHRONOUS ORBIT					
Intelsat IV F-1 1975-042A	A-Centaur	22 May		1436	35,800	35,772	0.1	1400	Comsat Communications Satellite - Last of the IV series Reimbursable
				GEOSYNCHRONOUS ORBIT					
Nimbus F (6) 1975-052A	Delta	12 Jun		107.3	1103	1093	99.96	832	Meteorological Satellite - R&D of instruments for expanding capabilities for remote sensing of the atmosphere - WTR
				SUN-SYNCHRONOUS POLAR ORBIT					
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NASA Major Launch Record

1975

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted)
OSO-I (8) 1975-57A	Delta	21 Jun		95.74	559.8	544.4	32.94	1052	Scientific satellite to study specific features of the Sun.
Apollo (ASTP) 1975-066A	Saturn IB	15 Jul	24 Jul	89.0	230	219	51.8	14,856 (CSM & DM)	Apollo Soyuz Test Project (ASTP) Manned: T. P. Stafford, V. Brand and D. K. Slayton - Docked with Soyuz 19 on 17 July Mission duration 217 hrs. 28 minutes
COS-B 1975-072A	Delta	8 Aug		2277	101,056	343	90.2	277	Cosmic Ray Satellite to study Extraterrestrial Gamma Radiation - *Launched for the European Space Agency (WTR). Reimbursable*
Viking-A (1) 1975-075A	Titan III Centaur	20 Aug	Lander 20 Jul 76	TRANS-MARS TRAJECTORY				Lander 1180 Orbiter 2360	Scientific Investigation of Mars - United States' first attempt to soft land a spacecraft on another planet. Successfully soft landed on 20 Jul 76 - First in situ analysis of surface material on another planet.
Symphonie-B 1975-77A	Delta	26 Aug		1436	35,800	35,772	0.1	402	Communications Satellite - French/German Cooperative - Reimbursable
				GEOSYNCHRONOUS ORBIT					
Viking-B (2) 1975-83A	Titan III Centaur	9 Sept	Lander 3 Sep 76	TRANS-MARS TRAJECTORY				Lander 1180 Orbiter 2360	Scientific Investigation of Mars - United States' Second attempt to soft land on Mars - Successfully soft landed on 3 Sep 76. Successfully returned scientific data.
Intelsat IVA F-1 1975 - 091A	A-Centaur	25 Sept		1436	35,792	35,779	0.1	1515	First in a series of improved COMSAT Communications Satellites- *Double the capacity of previous Intelsats. Reimbursable.*
				GEOSYNCHRONOUS ORBIT					

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NASA Major Launch Record

1975

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
AE-D (Expl. 54) 1975-096A	Delta	6 Oct	12 Mar 76	126.9	3816	154	90.1	675	Scientific satellite to investigate the chemical processes and energy transfer mechanisms which control Earth's atmosphere-WTR
U.S. Navy 1975-099A	Scout	12 Oct		95.3	703	359	90.7	160	Navy Transit Navigation Satellite - WTR - Reimbursable
SMS-C (GOES-A) 1975-100A	Delta	16 Oct		1443	36,082	35,775	1.0	628	*Geostationary Operational Environmental Satellite - Constructed* and launched by NASA - Funded and Reimbursed by NOAA.
				GEOSYNCHRONOUS ORBIT					
AE-E (Expl. 55) 1975-107A	Delta	20 Nov		118.0	3025	157	19.7	720	Scientific satellite to investigate the chemical processes and energy transfer mechanisms which control Earth's atmosphere.
DAD-A/B	Scout	5 Dec		ORBIT NOT ACHIEVED				A-40 B-43	Scientific satellite to measure global density of upper atmosphere and lower exosphere - Vehicle failed - WTR
RCA-A 1975-117A	Delta	13 Dec		1439	36,085	35,625	0.3	868	Communication Satellite - First RCA Domestic Communications Satellite (Reimbursable)
				GEOSYNCHRONOUS ORBIT					

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NASA Major Launch Record

1976

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Helios-B (2) 1976-003A	Titan III Centaur	15 Jan		HELIOCENTRIC ORBIT				370	Scientific satellite to investigate the properties in interplanetary space close to the Sun - Cooperative with Germany
CTS 1976-004A	Delta	17 Jan		1392	36,022	33,814	0.7	355	Experimental High Powered Communications Satellite - Cooperative with Canada
				GEOSYNCHRONOUS ORBIT					
Intelsat IVA-F2 1976-010A	A-Centaur	29 Jan		1424	35,901	35,216	0.1	1515	Comsat Communications Satellite - Reimbursable
				GEOSYNCHRONOUS ORBIT					
Marisat-A (1) 1976-017A	Delta	19 Feb		1436	35,867	35,703	2.4	317	Comsat Maritime Communications Satellite - Reimbursable
				GEOSYNCHRONOUS ORBIT					
RCA-B 1976-029A	Delta	26 Mar		1435	35,882	35,642	0.3	868	Second RCA (Satcom) Domestic Communications Satellite - Reimbursable
				GEOSYNCHRONOUS ORBIT					
NATO-III A 1976-035A	Delta	22 Apr		1436	35,791	35,783	2.2	310	Communications Satellite for the North Atlantic Treaty Organization - Reimbursable
				GEOSYNCHRONOUS ORBIT					
LAGEOS 1976-039A	Delta	4 May		225	5,944	5,835	109	411	To demonstrate the feasibility and utility of a ground-to-satellite laser system to contribute to the study of solid-earth dynamics. WTR
Comstar-1A 1976-042A	A-Centaur	13 May		1423	35,802	35,269	0.1	1490	Comsat's first Domestic Communications Satellite - Reimbursable
				GEOSYNCHRONOUS ORBIT					

1 lb = 0.4536 kg 1 mi = 1.609 km 1 NM = 1.8515 km

NASA Major Launch Record

1976

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Air Force Test 1976-047A	Scout	22 May		105	1058	994	100	73	To evaluate certain propagation effects of disturbed plasmas on radar and communications systems. Reimbursable - WTR
				SUN SYNCHRONOUS ORBIT					
Marisat-B 1976-053A	Delta	9 Jun		1436	35,807	34,788	2.5	317	Comsat Maritime Communications Satellite - Reimbursable.
				GEOSYNCHRONOUS ORBIT					
Gravity Probe-A	Scout	18 Jun		SUB-ORBITAL FLIGHT				102	Scientific probe to test Einstein's Theory of Relativity - WI
Palapa-A 1976-066A	Delta	8 Jul		GEOSYNCHRONOUS ORBIT OVER INDONESIA				575	Indonesian Communications Satellite - Reimbursable.
Comstar-B 1976-073A	A-Centaur	22 Jul		1425	35,747	35,388	0.2	1490	Comsat's Second Domestic Communications Satellite - Reimbursable
				GEOSYNCHRONOUS ORBIT					
ITOS-H 1976-077A	Delta	29 Jul		116	1,518	1,503	102	340	Meteorological Satellite - Redesignated NOAA-5 - Reimbursable WTR
U.S. Navy TIP 3 1976-089A	Scout	1 Sep		96	787	341	90	166	Transit Improvement Program (TIP) U.S. Navy Navigation Satellite - Reimbursable - WTR
Marisat-C 1976-101A	Delta	14 Oct		1436	36,525	35,051	2.6	317	Comsat Maritime Communications Satellite (Reimbursable)
				GEOSYNCHRONOUS ORBIT					

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NASA Major Launch Record

1977

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
NATO III B 1977 005A	Delta	27 Jan		104	35962	35463	2.8	670	NATO Communications Satellite - Reimbursable
					GEOSYNCHRONOUS ORBIT				
Palapa-B 1977 018A	Delta	10 Mar		1451	36250	35915	0.1	575	Indonesian Communications Satellite - Reimbursable
					GEOSYNCHRONOUS ORBIT				
GEOS/ESA 1977 029A	Delta	20 Apr		227	11710	241	26	575	ESA Scientific Satellite to investigate waves and particles in the magnetosphere - Rated unsuccessful by NASA - Reimbursable
					PLANNED ORBIT NOT ACHIEVED				
Intelsat IVA F-4 1977 041A	A-Centaur	26 May		1425	35755	35346	0.3	1515	Comsat Communications Satellite - Reimbursable
					GEOSYNCHRONOUS ORBIT				
GOES/NOAA 1977 048A	Delta	16 Jun		1436	36304	35267	0.9	635	Geostationary Operational Environmental Satellite - Second in a series launched for NOAA - Reimbursable
					GEOSYNCHRONOUS ORBIT				
GMS/Japan 1977 065A	Delta	14 Jul		1429	35779	35531	1.2	670	Geostationary Meteorological Satellite - First GMS launched for Japan - Reimbursable
					GEOSYNCHRONOUS ORBIT				
HEAO-A 1977 075A	A-Centaur	12 Aug		93.5	456	431	22.7	2551	Scientific Satellite - High Energy Astronomy Observatory to study and map x-rays and gamma rays.
Voyager-2 1977 076A	T-III Centaur	20 Aug		SOLAR SYSTEM ESCAPE TRAJECTORY				2080	Scientific Satellite to study Jupiter and Saturn Planetary Systems including their satellites and Saturn's rings.
SIRIO/Italy 1977 080A	Delta	25 Aug		1409	36327	34210	0.2	398	Scientific Satellite - Italian project to investigate trapped radiation flux, magnetic field intensity and variation, and the primary electron energy spectrum. Reimbursable
					GEOSYNCHRONOUS ORBIT				

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NASA Major Launch Record

1977

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Voyager 1 1977 084A	T-III Centaur	5 Sep		SOLAR SYSTEM ESCAPE TRAJECTORY				2080	Scientific Satellite - Second Voyager launched to investigate Jupiter and Saturn Planetary Systems.
OTS/ESA	Delta	13 Sep			ORBIT NOT ACHIEVED			865	Orbital Test Satellite. ESA experimental communications satellite. Vehicle Failure - Reimbursable
Intelsat IVA F-5	A-Centaur	29 Sep			ORBIT NOT ACHIEVED			1515	Comsat Communications Satellite - Vehicle Failure - Reimbursable
ISEE-A/B 1977 102 A&B	Delta	22 Oct		A-2.4 B-2.4	138124 138330	280 279	28.7 28.7	329 158	International Sun-Earth Explorer. Joint NASA/ESA mission to study the interaction of the interplanetary medium with Earth's immediate environment - Dual Payload - Cooperative
Navy Transat 1977 106A	Scout	28 Oct		107	1106	1067	89.9	93	US Navy Navigation Satellite - WTR - Reimbursable
Meteosat (ESA) 1977 108A	Delta	22 Nov		1411	35,692	34,913	0.7	697	ESA Meteorological Satellite - Europes contribution to the Global Atmospheric Research Program (GARP) - Reimbursable
					GEOSYNCHRONOUS ORBIT				
CS/Japan 1977 118A	Delta	14 Dec		1439	36,157	35,567	0.0	677	Communications Satellite (CS) - Launched for Japan Reimbursable
					GEOSYNCHRONOUS ORBIT				

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NASA Major Launch Record

1978

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Intelsat IVA F-3 1978 002A	A-Centaur	7 Jan		1436	35,794	35,780	0.3	1515	Comsat Communications Satellite - Reimbursable
				GEOSYNCHRONOUS ORBIT					
IUE-A 1978 012A	Delta	26 Jan		1436	45,869	25,722	28.6	700	International Ultraviolet Explorer to obtain high resolution data of stars and planets in the ultraviolet region of the spectrum. Cooperative with ESA.
FLTSATCOM-A 1978 016A	A-Centaur	9 Feb		1436	35,818	35,753	2.6	1863	Fleet Satellite Communications for the USN and the USAF - Reimbursable
				GEOSYNCHRONOUS ORBIT					
Landsat-C 1978 026A	Delta	5 Mar		103	914	890	99.1	900	Third NASA Earth Resources Technology Satellite - WTR Piggybacks - Oscar-8 & Plasma Experiment (PIX)
Intelsat IVA F-6 1978 035A	A-Centaur	31 Mar		1436	35,851	35,730	0.3	1515	Comsat Communications Satellite - Reimbursable
				GEOSYNCHRONOUS ORBIT					
BSE/Japan 1978 039A	Delta	7 Apr		1415	35,661	35,114	0.0	675	Broadcasting Satellite Experimental - Japanese Communications satellite for conducting TV broadcast experiments - Reimbursable
				GEOSYNCHRONOUS ORBIT					
HCMM/AEM-A 1978 041A	Scout	26 Apr		96.7	646	558	97.6	134	Heat Capacity Mapping Mission to produce thermal maps for discrimination of rock types, mineral resources, plant temperatures, soil moisture, snow fields and water runoff - WTR
OTS-B 1978 044A	Delta	11 May		1436	35,796	35,784	0.1	865	Orbital Test Satellite - ESA experimental communications satellite - Reimbursable.
				GEOSYNCHRONOUS ORBIT					

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NASA Major Launch Record

1978

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Pioneer/Venus-A 1978 051A	A-Centaur	20 May		TRANS-VENUS TRAJECTORY				582	Planetary mission to Venus. Orbiter to measure upper atmosphere and ionosphere, study interaction between solar wind and ionosphere and magnetic field, study atmospheric and surface characteristics, determine gravitational field harmonics.
GOES-C/NOAA 1978 062A	Delta	16 Jun		649	36,709	791	23.9	635	Part of global network of geostationary environmental satellites to provide Earth imaging, monitor the space environment, and relay meteorological data to users. Reimbursable
				GEOSYNCHRONOUS ORBIT					
Seasat-A 1978 064A	Atlas-F	26 Jun		100.6	798	775	108	2290	Sea Satellite for global monitoring of ocean geoid, wave topography, surface wind speed and direction, ocean surface temperatures, and ice field extent and dynamics - WTR
		Successful Rating to be Determined by the Seasat Review Board							
Comstar D-3 1978 068A	A-Centaur	29 Jun		629	35,852	550	21.8	1518	Third in a series of domestic communications satellites for Comsat - Reimbursable
				GEOSYNCHRONOUS ORBIT					
GEOS-B/ESA 1978 071A	Delta	14 Jul		626	35,542	213	25.8	575	ESA spacecraft to conduct scientific investigation of waves and particles in magnetosphere. Reimbursable
Pioneer/Venus-B 1978 078A	A-Centaur	8 Aug		TRANS-VENUS TRAJECTORY				898	Multiprobe - four hard landers - to determine nature and composition structure and general circulation pattern of the atmosphere of Venus from the surface to high altitudes.
ISEE-C 1978 079A	Delta	12 Aug		67,852	1,089,202	181	28.9	479	International Sun Earth Explorer. An extension of interplanetary studies with the spacecraft toward the Sun sufficiently outside the Earth's influence for comparison with results of ISEE-A and B missions and of probes to outer planets. Cooperative with ESA
Tiros-N 1978 096A	Atlas-F	13 Oct		102	865	850	98.9	1405	Polar orbiting operational spacecraft to provide improved meteorological data for NOMMS and provide support to GARP. Piggyback Payload (Oscar-7) - WTR

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NASA Major Launch Record

1978

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
Nimbus-G 1978 098A	Delta	24 Oct		104	954	953	99.28	987	Develop and flight test advanced sensors and technology basic to conducting experiments in the pollution monitoring, oceanographic and meteorological disciplines. A piggyback payload called CAMEO (Chemically Active Material Ejected in Orbit) was ejected to study the boundary structure between the polar cap and the auroral belt. WTR
HEAO-B 1978 103A	A-Centaur	13 Nov		95.3	543	522	23.5	3151	Second High Energy Astronomical Observatory to study very energetic radiation from space.
NATO-III C 1978 106A	Delta	19 Nov		632	35,891	184	27.2	706	NATO Communications Satellite - Reimbursable
					GEOSYNCHRONOUS ORBIT				
Telesat-D 1978 116A	Delta	16 Dec		632	35,896	185	27.3	442	Canadian Domestic Communications Satellite - Reimbursable
					GEOSYNCHRONOUS ORBIT				

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NASA Major Launch Record

1979

MISSION		DATE (GMT)		PERIOD	ORBITAL PARAMETERS			WEIGHT	MISSION/REMARKS
Name/Desig.	Vehicle	Launch	Down	(mins.)	Apogee (km)	Perigee	Incl.°	(kg)	(All launches from ETR, unless otherwise noted.)
SCATHA 1979 007A	Delta	30 Jan		HIGHLY ELLIPTICAL ORBIT ELEMENTS NOT MAINTAINED				658	USAF Scientific Mission - Spacecraft Charging at High Altitudes (SCATHA) to investigate electrical static discharges that effect satellites - Reimbursable
SAGE 1979 013A	Scout	18 Feb		96.7	661	548	54.9	127	Applications Explorer Mission (AEM-2) - Stratospheric Aerosol Gas Experiment (SAGE) - to map vertical profiles of ozone, aerosol, nitrogen dioxide, and Rayleight molecular extinction around the globe. WFC
FLTSATCOM-B 1979 038A	A-Centaur	4 May		GEOSYNCHRONOUS ORBIT ELEMENTS NOT MAINTAINED				1876	Fleet Satellite Communications to provide communications for the USAF and USN - Reimbursable
UK-6 1979 047A	Scout	2 Jun		97.3	658	596	55.8	155	United Kingdom Scientific Satellite to measure ultra-heavy cosmic ray particles and study low-energy cosmic x-rays. WFC - Reimbursable
NOAA-6 1979 057A	Atlas-F	27 Jun		101.3	826	810	98.8	723	Meteorological Satellite for the National Oceanographic & Atmospheric Administration - Reimbursable - WTR
Westar-C 1979 072A	Delta	9 Aug		GEOSYNCHRONOUS ORBIT				577	Domestic Communications Satellite for Western Union - Reimbursable
HEAO-3 1979 082A	A-Centaur	20 Sep		94.5	501	486	43.6	2898	High Energy Astronomy Observatory to survey cosmic rays and gamma rays.
Magsat 1979 94A	Scout	30 Oct		93.9	352	578	96.8	183	Applications Explorer Mission (AEM-3) to map the magnetic field of the Earth - WTR
RCA-C	Delta	6 Dec			19,323	90	23.8	895	Domestic Communications Satellite for RCA - Lost contact at Apogee Motor Firing. Reimbursable

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NASA Major Launch Record

1980

MISSION Name/Desig.	Vehicle	DATE (GMT) Launch	Down	PERIOD (mins.)	ORBITAL PARAMETERS Apogee (km)	Perigee	Incl.°	WEIGHT (kg)	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
FLTSATCOM-C	A-Centaur	17 Jan			GOESYNCHRONOUS ORBIT			1865	Fleet Satellite Communications to provide communications for the USAF and USN - Reimbursable
SMM-A	Delta	14 Feb		96	571	562	28.5	2315	Solar Maximum Mission to study the solar activity during the maximum of solar flares and related phenomena.
NOAA-7	Atlas-E	29 May		101	1434	267	92.2	1405	Meteorological Satellite for NOAA - Vehicle failed to place payload into proper orbit - WTR - Reimbursable
GOES-D	Delta	9 Sep			GEOSYNCHRONOUS ORBIT			832	Geostationary Operational Environmental Satellite for NOAA - Reimbursable
FLTSATCOM-D	A-Centaur	31 Oct			GEOSYNCHRONOUS ORBIT			1876	Fleet Satellite Communications to provide communications for the USAF and USN - Reimbursable
SBS-A	Delta	15 Nov			GEOSYNCHRONOUS ORBIT			1057	Satellite Business Systems (SBS) - Domestic Communications Satellite - Reimbursable System became operational March 1981.
INTELSAT V-A	A-Centaur	6 Dec			GEOSYNCHRONOUS ORBIT			1928	Comsat Communications Satellite - Reimbursable

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NASA Major Launch Record

1981

MISSION Name/Desig.	Vehicle	DATE (GMT) Launch	Down	PERIOD (mins.)	ORBITAL PARAMETERS Apogee (km)	Perigee	Incl.°	WEIGHT (kg)	MISSION/REMARKS (All launches from ETR, unless otherwise noted.)
Comstar D 1981 018A	A-Centaur	21 Feb			GEOSYNCHRONOUS ORBIT			1516	Comsat Domestic Communications Satellite - Reimbursable
STS-1 1981 034A	Shuttle (Columbia)	12 Apr	14 Apr	89.4	250	238	40.3	NA	First Orbital Flight - Commander John Young and Pilot Robert Crippen - Mission Duration 54 hrs. 21 min.
NOVA-1 1981 044A	Scout	15 May			NO ELEMENTS AVAILABLE			167	US Navy Navigation Satellite - Reimbursable - WTR
GOES-E 1981 049A	Delta	22 May			GEOSYNCHRONOUS ORBIT			837	Geosynchronous Operational Environmental Satellite for NOAA - Reimbursable
Intelsat V-B 1981 050A	A-Centaur	23 May			GEOSYNCHRONOUS ORBIT			1928	Comsat Communications Satellite - Reimbursable
NOAA-C 1981 059A	Atlas-F	23 Jun			GEOSYNCHRONOUS ORBIT			1405	NOAA Meteorological Satellite - Reimbursable - WTR
DE-A & B 1981 070 A & B	Delta	3 Aug		437.9 97.8	24,775 999	672 303	90.0 90.0	403 415	Dynamics Explorer - NASA scientific mission to study the Earth's electromagnetic fields. (Dual Payload) - WTR
FLTSATCOM-E 1981 073A	A-Centaur	6 Aug			GEOSYNCHRONOUS ORBIT			1876	Fleet Satellite Communications for DOD - Reimbursable
SBS-B 1981 096A	Delta	24 Sep			GEOSYNCHRONOUS ORBIT			1057	Satellite Business Systems - Domestic Communications Satellite - Reimbursable
SME 1981 100A	Delta	6 Oct		95.3	534	533	98.0	425	Solar Mesosphere Explorer - NASA scientific mission to study the nature and magnitude of changes in the mesosphere ozone.
STS-2 1981 111A	Shuttle (Columbia)	12 Nov	14 Nov	88.9	229	219	38.0	2542	Second Orbital Flight and the First Payload - Commander Joe Engle and Pilot Richard Truly-Mission Duration 54 hrs. 13 min. The OSTA-1 payload demonstrated the Shuttle's capabilities to conduct scientific research in the attached mode.
RCA-D 1981 114A	Delta	19 Nov			GEOSYNCHRONOUS ORBIT			1082	RCA Communications Satellite - Reimbursable
Intelsat V F-3 1981 119A	A-Centaur	15 Dec			GEOSYNCHRONOUS ORBIT			1928	Comsat Communications Satellite - Reimbursable

Abbreviations and Acronyms

ACN	Ascension
ACS	Attitude Control System
ADAU	Analog Data Acquisition Unit
ADP	Automatic Data Processor
AE	Atmosphere Explorer
AEC	Atomic Energy Commission
AFO	Announcement of Flight Opportunities
AGE	Automated Ground Equipment
AGO	Santiago, Chile
AOP	Advanced Onboard Processor
APT	Automotive Picture Transmission
ARC	Ames Research Center
ATM	Apollo Telescope Mount
ATS	Applications Technology Satellite
AU	Astronomical Units
BDA	Bermuda
BER	Bit Error Rate
C&DH	Communications and Data Handling
C&W	Caution and Warning
CCC	Central Command Control
CCIR	International Radio Consultive Committee
CM	Command Module
CMM	Command Memory Management
COMSAT	Communications Satellite Corporation
CP	Communications Processor
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CTC	Central Telemetry Control
CYI	Canary Islands
DDAU	Digital Data Acquisition Unit
DDPS	Digital Data Processing System
DET	Direct Energy Transfer
DMA	Direct Memory Access
DOD	Depth of Discharge
DPDT	Double-Pole Double-Throw
DPF	Data Processing Facility
DRL	Data Recuction Laboratory

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DSN	Deep Space Network
DSMA	Dilworth Second Meagaer and Associates, Ltd.
EED	Electrical Explosive Device
EGSE	Electrical Ground Support Equipment
EMC	Electro Magnetic Compatibility
EMI	Electro Magnetic Interference
EOS	Earth Observation Satellite
ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
ET	External Tank
ETR	Eastern Test Range
ETU	Engineering Test Unit
EVA	Extra Vehicular Activity
FMOC	Flight Maneuver Operations Center
FS	Factors of Safety
FSS	Flight Support System
GDS	Goldstone
GEOAP	Ground Equivalent Onboard Attitude Processor
GISS	Goddard Institute for Space Studies
GMI	Goddard Management Instruction
GMT	Greenwich Mean Time
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GTDS	Ground Tracking Data Station
GWM	Guam
HAW	Hawaii
HT	History Tape
I&T	Integration and Test
ICATS	Integrated Command and Telemetry System
I/O	Input/Output
IOC	Initial Operating Capabilities
IPD	Information Processing Division
IRA	Inertial Reference Assembly
IRAC	Interdepartment Radio Advisory Committee
IRB	Integrated Requirements Board
IS	Implementation Staff

Abbreviations and Acronyms (continued)

ISEE	International Sun Earth Explorer
IUE	International Ultraviolet Explorer
JPL	Jet Propulsion Laboratory,
JSC	Johnson Space Center
KSC	Kennedy Space Center (also known as Cape Canaveral, Cape Kennedy, Eastern Test Range, Merritt Island)
LARC	Langley Research Center
LTOF	Low Temperature Optical Facility
MAD	Madrid
MAM	Mission Adapter Module
MCC	Mission Control Center
MDAC	McDonnell Douglas Astronautics Company
ME	Main Engine
MEM	Module Exchange Magazine
MEMS	Module Exchange Mechanism System
MFR	Multi-Function Receiver
MIL	Merritt Island
MRB	Management Review Board
MSAD	Multisatellite Attitude Determination System
MSC	Manned Space Center, Houston, Texas
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Tracking Network
MWA	Momentum Wheel Assembly
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NASTRAN	NASA Structural Analysis
NBS	National Bureau of Standards
ND	Networks Directorate
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OAF	Optical Alignment Facility
OAO	Orbiting Astronomical Observatory
OAP	Onboard Attitude Processor
OBP	Onboard Processor

Abbreviations and Acronyms (continued)

OCC	Operations Control Center
OCCS	Operations Control Center Software
ODS	Orbit Determination Section
OGO	Orbiting Geophysical Observatory
OMS	Orbital Maneuvering System
OPF	Orbiter Processing Facility
ORR	Orroral
OSO	Orbiting Solar Observatory
OTDA	Office of Tracking and Data Acquisition
OTP	Office of Telecommunications Policy
PCM	Pulse-Code Modulated
PEL	Precision Elastic Limit
PI	Principal Investigator
PM	Phase Modulated
PMP	Premodulation Processor
POCC	Payload Operations Control Center
PSD	Power Spectral Density
PSK	Phase-Shift Keying
PSS	Payload Specialist Station
PWM	Pulse Width Modulated
QUI	Quito
RAD	Rapid Access Data
R&QA	Reliability and Quality Assurance
RBM	Real-time Batch Monitor
RCA	Radio Corporation of America
RCU	Remote Command Unit
RF	Radio Frequency
RF Comm Set	Radio Frequency Communications Set
RFI	Radio Frequency Interference
RI	Rockwell International Corporation
RMS	Remote Manipulator System
ROM	Read Only Memory
ROS	Rosman

Abbreviations and Acronyms (continued)

RSS	Root Sum Square
RSU	Relay Switching Unit
SAA	South Atlantic Anomaly
SOA	Smithsonian Astrophysical Observatory
SAS	Small Astronomy Satellite
SCE	Spacecraft Command Encoder
SCIA	Spacecraft Checkout and Integration Area
SCO	Subcarrier Oscillator
SDM	Structural Dynamics Model
SES	Space Environment Simulator
SIO	Special Input/Output
SM	Service Module
SPMS	Special Purpose Manipulator System
SRB	Solid Rocket Booster
STADAN	Space Tracking and Data Acquisition Network
STDN	Spaceflight Tracking and Data Network
STOP	Structural-Thermal-Optical Program
T&E	Test and Evaluation
TAN	Tananarive
TAR	Test Action Request
TDAS	Tracking and Data Acquisition System
TDPS	Tracking Data Processing System
TDRE	Tracking and Data Relay Experiment
TELOPS	Telemetry On-Line Processing System
TM	Thermal Model
TRW	Thompson Ramo Wooldridge Inc.
ULA	Fairbanks, Alaska
USB	Unified S-Band
UV	Ultraviolet
VAB	Vertical Assembly Building
VOB	Vacuum Optical Bench
WTR	Western Test Range, Vandenberg Air Force Base
ZOE	Zone of Exclusion

Abbreviations for Key Mission Participants

PM	Project Manager
PS	Project Scientist
PI	Principal Investigator
OI	Other Investigator
SC	Program Scientist
MG	Program Manager
TL	Team Leader
TM	Team Member
PE	Project Engineer
CO	Contact

NOTE: Names and affiliations of participants are generally as documented by the National Space Science Data Center, 1978-1981.

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